Community Preservation Committee
Town of Arlington

CPA Funding – FY2020 Final Application

One (1) electronic copy and three (3) hard copies of the completed application must be submitted to the CPAC **no later than 4 p.m. on December 10, 2018** in order to be considered for advancement to the final application stage, with the electronic copy sent to AFidalgo@town.arlington.ma.us and the hard copies to:

Community Preservation Committee c/o Amy Fidalgo
Town of Arlington, 730 Massachusetts Ave., Arlington, MA 02476

Applications will be date stamped and assigned control numbers in the order that the hard copies are received. This PDF form may be completed on a computer using AdobeReader.

1. General Information

Project Title: **Study of Spy Pond Field Bleachers**

Applicant/Contact: **Michael Rademacher, Director of Public Works**

Organization: **Arlington Department of Public Works**

Mailing Address: **51 Grove Street, Arlington, MA 02476**

Telephone: **781-316-3101** E-mail: **mrademacher@town.arlington.ma.us**

2. CPA Eligibility (refer to the chart on page A-4)

CPA Category (select one):

☐ Community Housing ☐ Historic Preservation ☐ Open Space **X** Recreation

CPA Purpose (select one):

☐ Acquisition ☐ Creation ☐ Preservation ☐ Support **X** Rehabilitation & Restoration

3. Budget

Amount Requested: **$50,000** Total Project Cost: **$50,000**

Signature: MW Date: 12/10/18

Please answer and document all questions on the following page

PROJECT DESCRIPTION: Attach answers to the following questions. Applications will be returned as incomplete if all requested information is not provided. Include supporting materials as necessary.

1. <u>**Goals**: What are the goals of the proposed project?</u>

Spy Pond Bleachers located on the northwest edge of Spy Pond Field.

The Arlington Public Works Department is eager to study and plan for the revitalization or replacement of the Spy Pond Field Bleachers. The original concrete bleacher construction dates back to 1910 and is in a significant state of disrepair. In 2014, a structural engineering consultant, expert in the restoration of concrete structures, was hired to evaluate its condition. A copy of the report is included with this application as appendix C. In summary, it was concluded that to repair/restore the structure would costs between $468,000 and $840,000 (2014 dollars) depending on the level of repair chosen. These costs do not include making the facility ADA compliant which would be necessary on such a project.

Archway entrance to the bleachers

Based on the current use of the bleachers and the estimated cost to repair, it would not be prudent to move forward with a restoration project of the existing structure without some review of the current use/need and input from the community.

With the help of a landscape architect/engineering consultant, the proposed study will evaluate the current use of the structure as well as engage the public and key stakeholders in order to map a future of the overall facility. It is expected that the study will include the following tasks:

- Survey existing site conditions to properly analyze possible re-use or repurposing of the current structure.
- Complete a Massachusetts Historical Commission Inventory Form “B” in order to record a description of the structure as well as document any/all historical significance associated with it.
- Evaluation of existing structure to review ways the bleacher seating can be made accessible in conformance with the Americans with Disability Act (ADA).
- Development of several conceptual level drawings for both reuse and new construction options with consideration of various field uses.
- A public input process to help guide the development of a desired concept.
- Development of conceptual cost estimates.

In summary, the goal of this project will be the development of a concept plan where the bleachers can support the use of the playing fields. Such a plan will be considered a success if the overall experience of visitors to the field is enhanced. Visitors could be competitors, spectators, Town Night fireworks viewers or simply individuals who come to enjoy one of the more pleasant public spaces in Arlington. In 2016, CBS Boston listed Spy Pond Field (Hornblower Field) as one of “Boston’s Best Baseball Fields” citing the following;

“The great draw of Spy Pond Field is its location. Nearby are the Spy Pond Park and Minuteman Bikeway, which has ten miles of paved path.” “In the summer, head over to Spy Pond Park after the game to cool off with a picnic.”

The area designated for visitors of Spy Pond Field to assemble should enhance the overall experience, not detract from it.

2. **Community Need**: Why is the project needed? Does it address needs identified in existing Town plans? If so, please specify.

   The existing structure is beyond its useful life and is in serious disrepair. Doing nothing is not an option as further deterioration will result in safety concerns.

Example of failing concrete

3. **Community Support**: What is the nature and level of support for this project? Include letters of support and any petitions.

   Aside from the basic requirement that Arlington maintain this structure to an appropriate standard, a neighborhood group has formed to petition the Town to take some action. A copy of their petition/design proposal is attached as appendix A. Letters of support are attached as appendix B

4. **Project Documentation**: Attach any applicable engineering plans, architectural drawings, site plans, photographs, any other renderings, relevant studies or material.

   An assessment of the bleacher structure was completed in 2014 by Wiss, Janney, Elstner Associates, Inc (WJE). WJE specializes in the study and evaluation of concrete structures. The report included a study of the structure's condition as well as cost estimates to make repairs. A copy of the report is included with this application as appendix C

5. **Timeline**: What is the schedule for project implementation, including a timeline for all critical milestones?

   Once funded, the proposed study will take between 4 to 6 months to complete.

   - Town Meeting CPA Approval - spring 2019.
   - Select Consultant - spring 2019.
   - CPA Funds Available - July 2019.
   - Survey/Existing Conditions - Jul/Aug 2019.
   - Concept Plan Development - Aug/Sept 2019.
   - Public Process - Oct 2019.
   - Refinement of Concept and Finalize Study - Nov 2019.
   - Spy Pond Bleacher Final Design CPA Application - Dec 2019.

6. **Credentials**: How will the experience of the applicant contribute to the success of this project?

   The Public Works Department regularly works with consultants to perform similar work. The DPW Director will be the lead on the project with support from the Engineering Department.

7. **Budget**: What is the total budget for the project and how will funds be sourced and spent? All items of expenditure must be clearly identified. Distinguish between hard and soft costs and contingencies. (NOTE: CPA funds may not be used for maintenance.)

   The total budget for this project is expected to be \$50,000 which includes a \$5,000 contingency. Funds will be used to hire a landscape architect/engineer to lead the work. A sub consultant, currently working with the Town's Historic Resources Working Group, will be hired to complete the Massachusetts Historical Commission Inventory Form "B".

8. <u>**Other Funding**: What additional funding sources are available, committed, or under consideration? Include commitment letters, if available, and describe any other attempts to secure funding for this project.</u>

   No additional funding sources are under consideration for the proposed study.

9. <u>**Maintenance**: If ongoing maintenance is required for your project, how will it be funded?</u>

   Any construction project ultimately resulting from this study will be maintained with the DPW's existing Operating Budget.

10. <u>**Impact on Town Budget**: What, if any, potential secondary effects will your proposed project have on the Town's Operating Budget? Are there any capital projects that rely on the successful completion of your project?</u>

    For this project to be ultimately successful, a plan which either renovates or replaces the existing structure will be chosen that will take into account the responsible use of future maintenance funds.

ADDITIONAL INFORMATION: Provide the following additional information, as applicable.

1. <u>**Control of Site**: Documentation that you have control over the site, such as a Purchase and Sales Agreement, option or deed. If the applicant does not have site control, explain what communications have occurred with the bodies that have control and how public benefits will be protected in perpetuity or otherwise.</u>

   The property is owned by the Town of Arlington, listed with the Assessor's Office as Map 10; Block 0005; Lot 0011.A.

2. <u>**Deed Restrictions**: In order for funding to be distributed, an appropriate deed restriction, meeting the requirements of Chapter 184 of Mass General Laws pursuant to section 12 of the Community Preservation Act, must be filed with the CPAC. Provide a copy of the actual or proposed restrictions that will apply to this project.</u>

   No known deed restrictions required by Chapter 184.

3. <u>**Acquisitions**: For acquisition projects, attach appraisals and agreements if available. Attach a copy of the deed.</u>

   No acquisitions required.

4. <u>**Feasibility**: Provide a list of all further actions or steps that will be required for completion of the project, such as environmental assessments, zoning approvals, and any other known barriers to moving forward.</u>

   There are no known barriers to completing the proposed study.

5. **Hazardous Materials**: Provide evidence that the proposed project site is free of hazardous materials or there is a plan for remediation in place.

   There are no known hazardous materials on site.

6. **Permitting**: Provide evidence that the project does not violate any zoning ordinances, covenants, restrictions or other laws or regulations. What permits, if any, are needed for this project? Provide the expected date of receipt for necessary permits, and copies of any permits already acquired.

   The proposed study would not require any permits.

7. **Environmental Concerns**: Identify all known wetlands, floodplains, and/or any natural resource limitation that occur within the boundaries of your submission.

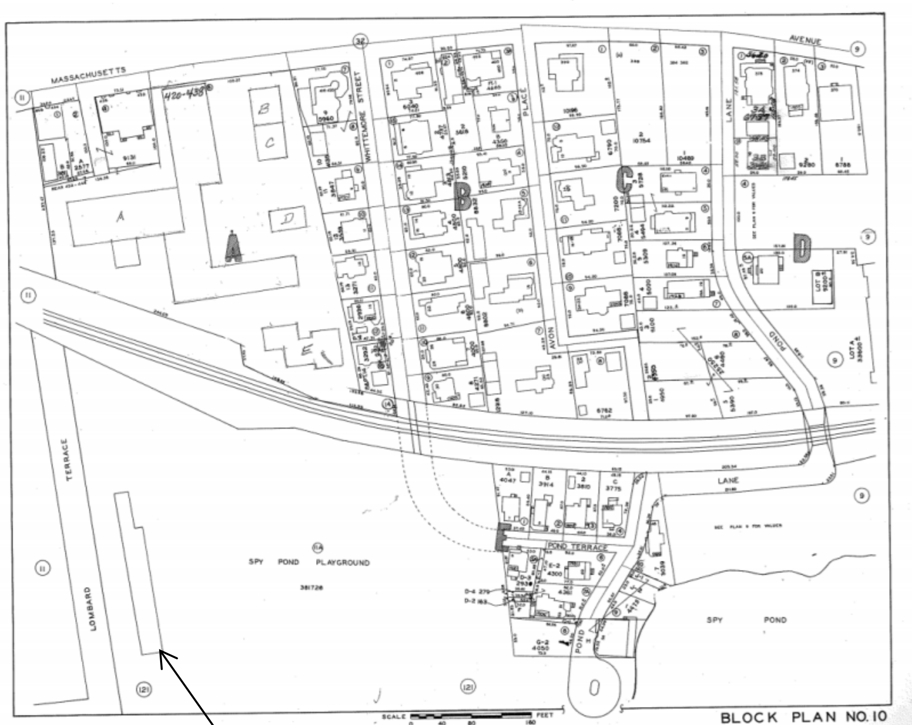
   No such environmental concerns exist at the study site.

8. **Professional Standards**: Evidence that appropriate professional standards will be followed if construction, restoration or rehabilitation is proposed. Evidence that the applicant and the project team have the proven or potential capacity to conduct the scope and scale of the proposed project, as evidenced by project leaders with appropriate qualifications and technical experience or access to technical expertise.

   The project will be managed by the Director of Public Works with input from the Town Manager's Office, Recreation, and the High School Athletic Department.

   The Public Works Department oversees the solicitation and award of similar projects on a regular basis.

9. **Further Attachments**: Assessor's map showing location of the project.



Spy Pond Bleachers

APPENDIX A

Neighborhood Design Petition

Spy Pond Field
Neighborhood Input - Future Renovations
April 2017

Steve Opie and Charlotte Heim (44 Lombard Terrace) with input from neighborhood residents (*Meg Candilore, Paul Candilore, Ben Clark, John Girash , Reebee Girash, Phillip Sharff, Robin Lord, Cary Coovert)*

<u>Let's build an amphitheater instead of a grandstand!</u>
(see more info at the end of the document)

Resources: Spy Pond Field – Assessment of Concrete Bleachers – Completed 1/17/14, Town of Arlington Open Space and Recreation Plan 2016-2022 (Section 2-C-2)

<u>A. Neighborhood Concerns:</u>

- Town should engage in a "thoughtful assessment" that reviews the year-round usage and looks at the associated structures in addition to the stadium including stairways to the field, retaining walls, street erosion, and the fence along Lombard Terrace.
- The current stadium and associated structure have deteriorated into an eyesore.

- Neighbors have concerns about safety, trash, and youth behavior on field at night.
- There is some historical value to the stands but neighbors are not married to the old structures particularly in the current state of disrepair.
- Metal bleachers as a replacement to the stands would ***not*** be a welcome solution.
- Consider ADA accessibility for the field and stadium seating.
- Design should include shade trees for spectators, provide a clear line of sight from all perimeter streets to reduce unacceptable activities, and minimize vertical surfaces to reduce tagging.

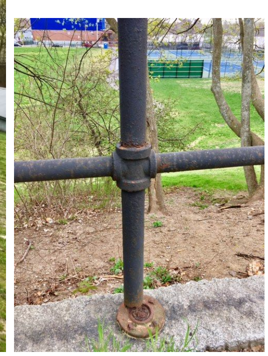
B. Current of the Field Uses : *Planning for renovations should look beyond the repair or replacement of the concrete stadium and encompass the many, year-round uses of the field.*

Field Use	Time of Year	Comments
Dog Walking	Year Round	Off leash sunrise- 9AM (approximately 50 dogs counted on a Sunday in April, 2017)
Baseball	April to August	Largest user of stadium; however stands are rarely used. People often seek shade along bike path or near oak tree near the stairs.
Soccer	Fall	Spectators bring own chair, lines are drawn on field, goalie nets are kept on field.
Town Day	Evening in September	This is the largest crowd of the year. Activities include train rides, vendors, pony rides, food vendors, entertainment, shaving cream fight.
Athletic Training	Spring-Fall	Various high school teams run stairs on the stadium, workout classes are held in the field
Sledriding	Winter	Involves hill next to stadium toward Wellington along Lombard Terrace.
Youths congregating in stadium at night	Year Round	On a weekly basis youths congregate on stadium stairs and utilize walls of stadium to obstruct view from Lombard Terrace. Youths regularly consume alcohol, smoke, and leave behind trash and broken glass. Tagging occurs occasionally.

C. Current Issues with Spy Pond Field Infrastructure

Stadium Structure	
2014 Assessment ● Crumbling concrete ● Exposed rebar	

	
 	
Graffiti/Tagging	
All vertical surfaces are regularly tagged.	
Stairs at end of Lombard Terrace	

Granite wall on right is unstable due to erosion.	
Erosion along Lombard Terrace	
	
Fence	
The 100+ year old, original fence is broken and unstable in many places along Lombard Rd.	 

<table>
<tr><td colspan="2">Exposure of retaining wall</td></tr>
<tr><td>Retaining wall on the “sled riding hill” has just started to surface in the past 2 years.</td><td></td></tr>
<tr><td colspan="2">Wall - creating cliff next to sledding hill</td></tr>
<tr><td>Every few years a child goes flying over this wall which can be hard to see from the top of the sled riding hill.</td><td></td></tr>
<tr><td colspan="2">Disrepair backstop and dugout building.</td></tr>
</table>

Chain link is bent with holes and portions bending out.	
Roof on dugout has ragged metal edge. Children regularly climb on the roof.	Need to take a photo of

D. Design idea for potential replacement of concrete stadium - Grade slope so there is a clear view of field from Lombard Terrace and imbed granite slabs for seating. Cost effective, more community uses, and aesthetically more pleasing.

APPENDIX B

Letters of Support

TOWN OF ARLINGTON

Director of Recreation *Jon Marshall*

RECREATION DEPARTMENT

CPAC Committee

Dear CPAC Committee,

I am writing in support of the Town of Arlington's application to study the Spy Pond stands and bathrooms. This study will give the town a better understanding of what needs to be addressed. The current condition of these amenities is in need of major repairs, replacement or even removal.

Each spring since I have been with the department we have discussed the need to address these conditions at the site. There is no simple fix and it is important to understand the impact of any major undertakings. This study should give the departments that have oversight of Spy Pond; Public Schools, Public Works and Recreation, the ability to properly plan for what should take place.

Sincerely,

Jon Marshall
Director of Recreation

422 Summer Street, Arlington, Massachusetts 02474
Telephone (781) 316-3880 Fax (781) 641-5495

Stanley Vieira
Athletic Director
Arlington High School
869 Massachusetts Avenue
Arlington, MA 02476

To Whom It May Concern:

I am writing this letter of support to study the facilities required at Spy Pond Field. We use Spy Pond for many of our Arlington High School athletic teams and the field presents many challenges regarding spectator seating, inadequate bathrooms and locker rooms and no storage for any of our equipment.

I believe an upgrade would not only benefit the high school, but also the town with the ability to do much more in the way of additional programming for youth and adult programs.

Please let me know if you have any questions.

Yours in Sport,

Stanley Vieira
Athletic Director
Arlington High School
781-316-3551

From: Robin Lord <rlord57@hotmail.com>
To: "MRademacher@town.arlington.ma.us" <MRademacher@town.arlington.ma.us>
Date: 12/06/2018 01:30 PM
Subject: Neighbor in support of Spy Pond Grandstand Initiative

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Hello Mr. Rademacher,

My family and I live in the Spy Pond neighborhood. Our neighborhood group is pleased that the Arlington Community Preservation Committee has approved the request for preliminary application for conceptual improvement plans to the Spy Pond Bleachers.

I understand from my neighbor, Steve Opie, that you have seen a document with an outline of our neighborhood concerns, the current uses of the field, the current issues with Spy Pond Field infrastructure and a vision of a tear-down of the grandstand and a low impact graded slope resolution.

We also wanted to commend your efforts on including our neighborhood's input and our participation in the revitalization of the area. We love living here, enjoying the closeness of the park and the many advantages that we have grown to appreciate.

Best regards,
Robin

Robin Lord
46 Lombard Terrace
Arlington, MA
02476

APPENDIX C

Engineering Study of Existing Bleachers

SPY POND FIELD
Assessment of Concrete Bleachers

Arlington, Massachusetts

Final Report
January 17, 2014
WJE No. 2013.4548

Prepared for:
Mr. Michael Rademacher
Director of Public Works
Town of Arlington
Department of Public Works
51 Grove Street
Arlington, Massachusetts 02476

Prepared by:
Wiss, Janney, Elstner Associates, Inc.
311 Summer Street, Suite 300
Boston, Massachusetts 02210
617.946.3400 tel | 617.946.0740 fax

SPY POND FIELD
Assessment of Concrete Bleachers

Arlington, Massachusetts

Joe Standley
Associate III

Emma Cardini, PE
Senior Associate

Final Report
January 17, 2014
WJE No. 2013.4548

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WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

SPY POND FIELD
Assessment of Concrete Bleachers

Arlington, Massachusetts

INTRODUCTION

Spy Pond Field, located in Arlington, Massachusetts, is a multi-use sports field that includes a concrete bleacher structure with an attached concrete locker room and maintenance building. The field is bordered on the northwest by Lombard Terrace, the southwest by Wellington Street, the southeast by Pond Street, and the northeast by the Minuteman Commuter Bikeway (Figure 1). The concrete bleachers are aligned parallel with Lombard Terrace and are set into a hillside adjacent to Lombard Terrace (Figure 2). The bleachers are approximately 170 feet long (parallel to Lombard Terrace) and 32 feet deep. Pedestrian access to the top of the bleachers is through a concrete walkway off of Lombard Terrace that passes under a concrete archway (Figure 3). There are also three field-level entrances located at the center and each end of the bleachers. Southwest of the bleachers is a concrete site stairway that is also set into the hillside (Figure 4). The stairs connect Lombard Terrace with the field below.

The bleachers consist of a combination of original cast-in-place concrete (circa 1910) and newer precast concrete elements (circa 1987). The original cast-in-place concrete comprises the archway, the four perimeter walls, sub-structures (foundation walls, piers, footings, raker beams), the locker rooms/maintenance building, and the walkway at the bottom of the bleachers. The precast concrete comprises the seating elements that were installed during a renovation in 1987 (Figure 5).

Michael Rademacher of the Town of Arlington Department of Public Works (Arlington DPW) requested that WJE assess the concrete structure in an effort to determine the extent of repairs necessary to restore the safety and serviceability of the bleacher structure, as well as reduce potential maintenance going forward. Arlington DPW also requested that WJE determine if replacing the bleachers and archway with new could be more cost-effective than repair.

DOCUMENT REVIEW

WJE was provided with drawing sheets S-1 and S-2 titled “Spy Pond Grandstand Rehabilitation” developed by Tsiang Engineering and dated March 11, 1987. We noted the following during our review:

- The 1987 repair work included installation of new precast concrete seating elements placed across the existing concrete raker beams. Notes regarding the existing concrete to remain in place indicate that it was repaired and sealed or painted. Repair details provided on sheet S-2 indicate that cracks were routed and sealed and that spalled and loose concrete was removed and patched.
- The typical precast concrete seating elements are “L”-shaped in section and approximately 31 inches wide, 3.5 to 4 inches thick, and 15 inches tall (Figure 6). Four-inch by four-inch galvanized welded wire fabric is located at the center of the cross-section. There are parallel number 4 galvanized bars at the end and at the base of each precast concrete seating element.
- Notes regarding concrete and reinforcing steel are provided on sheet S-2. The notes indicate that all concrete shall have a 28-day compressive strength of 4,000 psi, air entrainment of 5 to 6 percent, and a water-cement ratio not to exceed 0.5 by weight. All precast concrete elements were to conform to the requirements of PCI Manual #117.

- New vertical expansion joints were added to the existing concrete wall at the base of the bleachers. The expansion joint detail involved saw cutting a groove at existing cracks and filling the groove with backer and sealant. Notes indicate that spalls and cracks around the joints were to be repaired.
- A new roofing membrane was detailed to be installed over the portion of the locker room building that extends beneath the bleachers.

FIELD INVESTGATION

WJE first visited the site on September 5, 2013 and conducted a follow-up field survey on November 15, 2013. During our survey we documented existing conditions, removed loose concrete overhead at the archway and west pillar, sounded approximately 50 percent of the seating elements and walls by hammer tapping, removed some loose concrete from seating elements and perimeter walls, and observed concrete coring performed by a concrete coring contractor to be used for petrographic analysis. WJE also performed petrographic analyses on the obtained samples. Our field and petrographic observations are summarized in the following sections based on element/structure type. Refer to the annotated plan drawing shown in Figure 38 at the end of this report for a graphical representation of select observations.

Cast-in-Place Concrete

Archway

The lower portion of the concrete archway is cracked and experiencing widespread coating failure (Figure 7). There is a crack approximately 1/2 inch wide where the arch element intersects the west vertical column (Figure 8). This crack was previously repaired with mortar or sealant. The pediment above the concrete archway is significantly deteriorated at the horizontal surfaces and corners (Figure 9). Large concrete spalls, up to two feet long, were easily removed by hand during our field work (Figure 10). Biological growth is present at various locations on the pediment, indicating persistent exposure to moisture (Figure 11).

Perimeter Walls

The perimeter walls at the sides and top of the bleachers are approximately three inches thick with a coping approximately five inches wide. These walls are typically cracked throughout and there are multiple spalls or incipient spalls with exposed corroded reinforcing steel (Figure 12). At the rear perimeter wall, there is a continuous horizontal crack that is approximately 1/2-inch wide, just below the coping (Figure 13).

The perimeter wall at the base of the bleachers is approximately six inches thick and the outside vertical surface is treated with a grey coating. There are approximately ten vertical cracks within the wall, some of which are located at construction/control joints, and some that are accompanied by isolated areas of delaminated concrete (Figure 14). Approximately 50 to 75 percent of the top surfaces of the perimeter walls are delaminated.

Decorative Pillars

Decorative concrete pillars are located at each end of the upper perimeter wall. The pillars are square in plan and include a flat pediment with a concrete sphere at the top. The coating at both pillars has failed. At the west pillar there is a vertical concrete spall at the northeast corner that is approximately three feet long with exposed corroded reinforcing steel (Figure 15). The pediment at the top of this pillar is also spalled and there are vertical cracks extending from the body of the pillar up through the pediment

(Figure 16). The east pillar is less deteriorated; however, there is one vertical crack approximately four feet long located on the north face of the pillar in addition to four abandoned embedded anchors (Figure 17).

Walkway and Field-level Stairs

The concrete walkway at the base of the bleachers is typically in good condition with minimal distress. The field-level stairway at the east end of the bleachers is in poor condition with multiple cracks and spalls throughout (Figure 18). WJE attempted to remove a concrete core from a stair tread and noted the presence of large aggregate (up to 2 inches in diameter) and minimal cement paste.

Precast Concrete Seating Elements

A fine network of interconnecting cracks ("map" cracking) is present on the horizontal surfaces at one or both ends of 31 of the 70 (approximately 44 percent) precast concrete seating element sections (Figure 19). Similar map-cracking is present at the sloped transition between the horizontal and vertical surfaces at most of the precast concrete seating elements (Figure 20). At isolated locations there is more pronounced cracking of the sloped transition and vertical surfaces at the ends of the seating elements (Figure 21). Control joints between precast concrete sections and along the perimeter walls are detailed with sealant and backer rod but the sealant joints have typically failed in adhesion or cohesion (Figure 22). Control joint widths vary from less than 1/4 inch to larger than 1 inch (Figure 23).

There are shrinkage cracks in the concrete pour strip installed between the precast concrete seating elements and the perimeter walls that run perpendicular to the walls (Figure 24). Cracking is also prevalent throughout each of the precast concrete stair treads that are located in the center of the bleacher structure between the field and the archway (Figure 25).

During our first site visit, WJE observed seven existing concrete spalls located at the ends of precast concrete seating elements (Figure 26). When we returned for the full survey, these spalls had been repaired by others (Figure 27). Additional spalls at the edge of one seating element (adjacent to a patch repair) were not yet repaired (Figure 28). During the field survey, WJE also removed delaminated concrete at one seating element location that had not previously been repaired (Figure 29).

Maintenance and Locker Room Building

The west end of the maintenance and locker room building extends under the concrete bleachers. Portions of the foundation and perimeter walls are visible from inside the restroom/shower area. There are three windows at the rear perimeter wall that open to the restroom/shower area; two are boarded up with an opaque infill panel (Figure 30) and the other filled with a Plexiglas panel in a rotted wood frame covered by a corroded and displaced metal grate (Figure 31). It appears that the ceiling of the restroom/shower area is constructed of board-formed concrete, which is assumed to be a separate structure from the precast concrete seating elements above. There is evidence of ongoing water penetration at the ceiling in the form of staining and peeling coating (Figure 32).

The remaining portion of the maintenance and locker room building lies outside of the bleachers and is covered by a corrugated sheet metal roof (Figure 33). There is a large horizontal crack at the northeast corner of the building measuring approximately 1/2-inch wide with peeling coating on all three sides of the building (Figure 34).

Site Stairs

The site stairs adjacent to the bleachers contain areas of spalled and cracked concrete on the foundation walls on both sides of the treads (Figure 35). The spalled areas range in size from about two square feet up to ten square feet. Other sections of the foundation walls appear to be delaminated (Figure 36). The stair treads are less deteriorated but there are visible spalls and cracks (Figure 37). Some treads appear to have been patched previously. There are no handrails along the stairway.

PETROGRAPHIC ANALYSIS

WJE obtained nine concrete samples from various locations for the purpose of petrographic study. Samples are described in the table below. The full petrographic report is appended to this report and the results are summarized in the following sections.

Table 1. Concrete Samples

Sample ID	Location	Sample Size
1	Precast concrete seating element - seating surface adjacent to spalled concrete	3” dia. cylinder, 3” long
2	Precast concrete seating element - seating surface	3” dia. cylinder, 3” long
3	Precast concrete seating element - central stair with map-cracking throughout	3” dia. cylinder, 7.75” long
4	Precast concrete seating element - seating surface	3” dia. cylinder, 3” long
5	Precast concrete seating element - seating surface adjacent to spalled concrete	3” dia. cylinder, 3” long
6	Walkway at bottom of bleachers	3” dia. cylinder, 4.5” long
Archway	Top of pediment at concrete archway	6” x 4” x 7.5” wedge
Coping	Top of rear foundation wall	2” x 3” x 9” rectangle
Pillar	Top of decorative pillar at northwest corner	3” x 3” x 5.5” wedge

Cast-in-Place Concrete

The pillar and coping samples both exhibit advanced freeze-thaw distress. Neither sample is air-entrained. There is a thin mortar layer on the horizontal surface of the coping sample that was most likely installed in an effort to increase the durability of the element. This layer has a conspicuously lower water to cement ratio than the underlying body of the concrete and would be expected to reduce water penetration into the element. Subsequent cracking of the coping allowed water penetration into the non-air-entrained body of the element.

The fragment of the historic archway is composed of a mortar-like mix that is functionally air-entrained. It has a relatively high cement factor compared to the coping and pillar fragments. Since mortars typically have higher cement factors, they often have lower water to cement ratios than concrete. The archway sample does not exhibit freeze-thaw distress.

No evidence of alkali-silica reaction (ASR) was present in these three samples of historic concrete.

Sample 6 represents an entirely different concrete mix than the other samples. Although concrete represented by this sample has an elevated water to cement ratio and is deficient in coarse aggregate volume, it is air-entrained and does not exhibit freeze-thaw-related distress.

Precast Concrete Seating Elements

Concrete samples 1 and 5 are non-air-entrained and contain fractures that are indicative of advanced freeze-thaw distress. Secondary deposits that coat these fracture surfaces confirm that moisture has migrated through the concrete. Although samples 2, 3, and 4 are air-entrained, secondary deposits were detected in many of the air voids. In addition to the variation in air entrainment, there is also a variation of the constituent volumes of materials from sample to sample.

Evidence of active ASR is present in all five of the precast concrete bleacher samples. The ASR distress appears to be localized near the bottoms of the samples. The concrete is made with crushed fine-grained metamorphic coarse and fine aggregate that has textural features consistent with both quartzite and phyllite. This type of aggregate is classed as potentially deleteriously reactive with cement alkalis. The presence of silica gel in voids and along fractures located in the lower portions of the samples in combination with internally fractured coarse aggregate particles that exhibit darkened rims is consistent with deterioration due to ASR.

Some of the observed intact aggregate particles are encompassed by a rim of anisotropic (crystalline) material composed of ettringite.

The bottom of sample 3 was tested for compression strength according to ASTM C42 as it was the tallest core removed. The compression strength of the core was 8,730 psi. Sample 3 is air-entrained, and no evidence of freeze-thaw distress was detected in the portion of the submitted sample that was examined petrographically. Evidence of deleterious expansion due to ASR was detected in the top portion of sample 3 examined microscopically. Even if cracking associated with freeze-thaw or ASR-induced distress was present, if the planes of the cracks were oriented perpendicular to the axis of the core used for compression strength evaluation, a significant decrease in strength may not be detected.

DISCUSSION

The cast-in-place architectural concrete of the pillar and coping exhibit freeze-thaw distress typical of non-air-entrained concrete from circa 1910. This distress is expected to continue and may increase in rate over time. Although freeze-thaw distress was not confirmed in the petrographic study of the archway concrete sample, there is visible evidence that other portions of the archway have experienced distress related to freeze-thaw cycling, which indicates that the archway concrete mix is variable.

Most of the cast-in-place concrete structural elements such as the below-grade foundation walls and raker beams could not be examined because they are concealed by the precast concrete seating elements. It is likely that these elements are constructed of a similar concrete mix and therefore would also be susceptible to freeze-thaw distress.

The cast-in-place concrete at the lower level walkway is air-entrained and does not exhibit freeze-thaw distress. In general this concrete is in good condition.

Freeze-thaw resistance of concrete is primarily affected by two characteristics of the concrete mix design; air-entrainment and water-cement ratio. Air-entrainment involves the intentional introduction of

microscopic spherical air bubbles within the cement paste. When water within the cement paste expands as it freezes, water displaced by ice formation flows into these air bubbles, thus relieving the hydraulic pressure build-up. The water-cement ratio also affects freeze-thaw resistance because it affects the permeability of the concrete; lower water-cement ratio concrete mixes are less permeable. A concrete mix that contains 5 to 8 percent air entrainment and a low water-cement ratio will provide a significantly higher level of freeze-thaw durability compared to a mix with no air entrainment and a high water-cement ratio.

Map-cracking is present throughout the precast concrete bleacher seating elements. The two samples removed from areas adjacent to spalled precast concrete were the two samples that were determined through petrographic analysis to be non-air-entrained. At these locations the concentration of map-cracking is greater. Although some of the precast concrete samples are air-entrained, secondary deposits in many of the air voids would be expected to reduce the effectiveness of the air void system. Thus concrete represented by these samples may eventually become susceptible to freeze-thaw distress similar to that observed in the samples that are not air entrained.

ASR is detected in all of the precast concrete samples. ASR is a phenomenon that occurs in some concrete materials when the alkaline cement paste causes silica in the aggregate to convert into alkali-silica gel. The gel expands with exposure to water, resulting in the accumulation of internal forces within the cement matrix. Eventually, these forces cause cracking of the aggregate and surrounding cement paste. ASR is a relatively slow process that typically results in serviceability problems such as cracking and spalling, but it can accelerate other deterioration mechanisms. ASR is typically the result of poor aggregate selection, or reactive aggregate contaminants in the aggregate used for precast concrete.

The presence of a few aggregate particles that are surrounded around their perimeters by ettringite has previously been detected in concrete that has suffered from deleterious expansion of the matrix associated with delayed ettringite formation (DEF). Since secondary deposits of ettringite are also associated with freeze-thaw distress, additional studies using the scanning electron microscope would be necessary to fully characterize these features of the cementitious matrix in an attempt to determine if DEF may also have contributed to the observed distress.

Air entrainment and water-cement ratio are inherent with the original mix design and thus cannot be altered after the concrete is placed. ASR and DEF are material-related phenomena that can lead to accelerated deterioration of the concrete materials. The significant sample-to-sample variation in aggregate volumes and levels of air entrainment are consistent with batch-to-batch variations in the concrete used to fabricate the bleacher seating and stair elements represented by samples 1 through 5.

There is evidence of long-term water infiltration at the maintenance/locker room building. Water that enters the building through the ceiling, damaged window infills, or through cracks in the concrete walls can result in damage to the interior finishes and further deterioration of the concrete structure.

CONCLUSIONS AND RECOMMENDATIONS

The conditions of the concrete archway, pillars, and site stairs are consistent with their age, material properties, and the result of deferred maintenance over a prolonged period. The distress observed at bleachers is representative of the material properties and distress mechanisms identified through petrographic analysis; specifically, it appears that deterioration is most concentrated at non-air-entrained precast concrete elements. This deterioration is expected to continue if the deficient material is not

replaced or protected in some manner from further ingress of moisture, which is a necessary component to these deterioration mechanisms.

WJE understands that these bleachers are used by Arlington High School and for other town events; events like Arlington Town Day that occurs annually in September bring in several thousand people. As the concrete continues to deteriorate, it will crack and spall and may become a public safety hazard. WJE recommends the following repair options to restore the bleachers to a safe and serviceable condition that minimizes future maintenance requirements. Due to the comprehensive nature of these repair options, it may be necessary to consider upgrading the facility to be accessible for those with physical disabilities. WJE recommends that the Town of Arlington engage a code consultant to determine what alterations may be required to comply with the Americans with Disabilities Act, or other jurisdictional requirements.

Option A: Repair Existing Concrete

This option includes repairing salvageable portions of the bleachers and replacing those elements that are no longer serviceable. This repair option does not fully address the underlying material deficiencies at the precast concrete seating elements, but is intended to slow the rate of deterioration by reducing future water penetration into the vulnerable concrete materials through the application of a traffic-grade elastomeric coating. New concrete elements will have an expected service life of 30 years, while the coating will have an expected service life of 5 years. Note that the condition of the foundation walls and raker beams concealed by the visible concrete elements is not known; this repair option does not allow for any additional visual observations.

We recommend the following scope of work for Option A repairs:

- Demolish perimeter walls down to the grade-level foundation walls and install new cast-in-place concrete perimeter walls doweled into the existing walls below. Increase the wall thickness to a minimum of four inches to provide adequate concrete cover for reinforcing steel.
- Replace archway with new precast concrete archway.
- Replace pillars with new precast concrete pillars.
- Replace delaminated concrete on top of and at vertical surfaces of lower perimeter wall. Patch wall areas at vertical cracks and control joints. Remove coating from wall.
- Replace all three field-level staircases.
- Saw-cut expansion joints to be at least 1/2-inch wide between precast concrete seating elements to widen joints. Replace all sealant and backer rod at all control joints.
- Remove temporary patch material and square off repair areas at precast concrete seating elements. Repair with concrete patches properly designed and mechanically anchored to optimize service life.
- Clean concrete surfaces by abrasive blasting or water jetting.
- Apply new traffic-grade elastomeric coating to surfaces of precast concrete seating elements.
- Apply new elastomeric coating to all other concrete elements.
- Remove spalled and delaminated concrete and install mechanically-anchored concrete patches at site stairs and overhead concrete at interior of maintenance/locker room building.
- Replace window infills and window at maintenance/locker room building and repair crack at northeast corner of the building.

Option B: Replace Bleachers

This option completely replaces the precast concrete seating elements, perimeter walls, and archway to limit the risk of future damage and reduce routine repair and maintenance. Design of the new precast and

cast-in-place concrete could resemble the existing construction, if desired. It is expected that the existing foundation walls, raker beams, and maintenance/locker room building can be reused but may require limited structural repairs to address deficiencies or reduce the potential for future deterioration. A review of these structural elements will be necessary once the existing precast concrete seating elements have been removed. This option will provide a longer overall service life than Option A, be more durable, and require less maintenance than Option A, but at likely a higher initial cost.

OPINION OF COST

WJE has prepared a rough order of magnitude opinion of construction costs to compare the above-described repair options. The opinion of construction cost estimates are shown in the tables included in the Appendix. These estimates do not include fees for architect or engineer repair design or construction oversight. Opinions of probable costs are based upon our visual observations only and should be considered preliminary. Actual repair costs may differ depending on the bidding climate, on detail design, and on unforeseeable or concealed conditions. Opinions of probable costs are intended to provide an order of magnitude for budgetary considerations. If more precise estimates are required, further investigation and testing can be conducted, repair documents can be prepared, and bids can be obtained from qualified contractors.

FIGURES

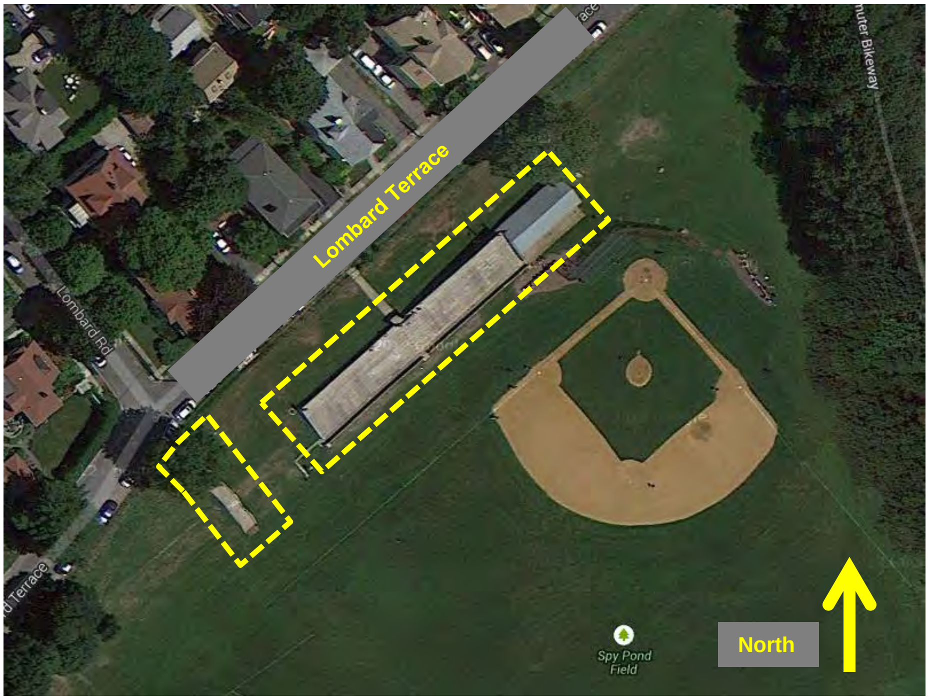

Figure 1. Google maps image showing Spy Pond Field, concrete bleachers, and site stairs.

Figure 2. Overall view of bleachers from southwest.

Figure 3. Concrete archway at top of bleachers.

Figure 4. Site stairs leading from Lombard Terrace down to field level.

Figure 5. Precast concrete seating elements.

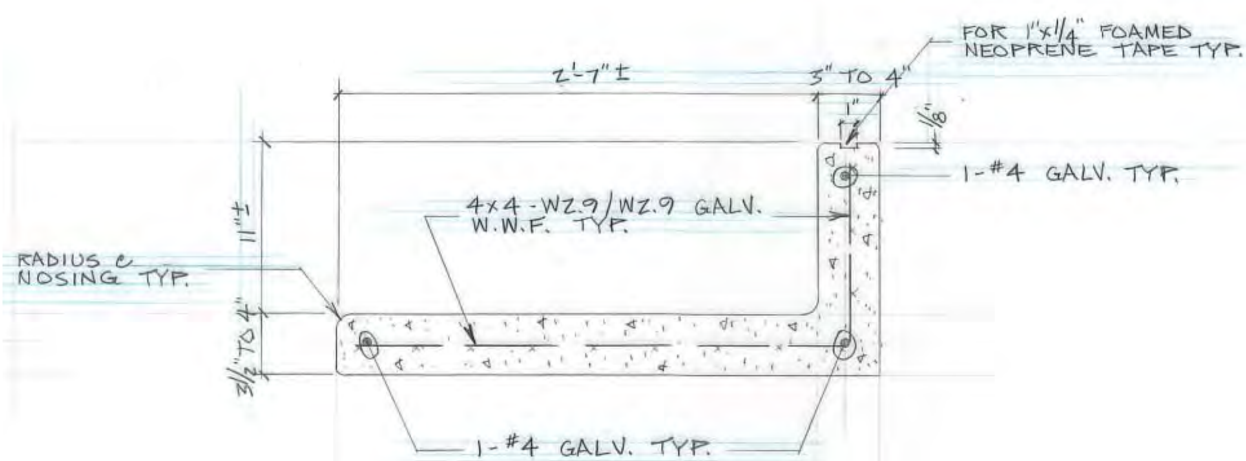

Figure 6. Typical precast concrete seating section as shown in 1987 renovation drawings.

Figure 7. Cracking and coating failure at base of concrete archway.

Figure 8. Previously repaired crack where arch intersects column.

Figure 9. Typical concrete deterioration at pediment above arch.

Figure 10. Loose concrete sections removed form arch and pediment.

Figure 11. Biological growth at distressed concrete above arch.

Figure 12. Perimeter wall with typical spalling and cracking.

Figure 13. Horizontal crack below coping at rear perimeter wall.

Figure 14. Perimeter wall at base of bleachers with cracks and spalled concrete at control joint.

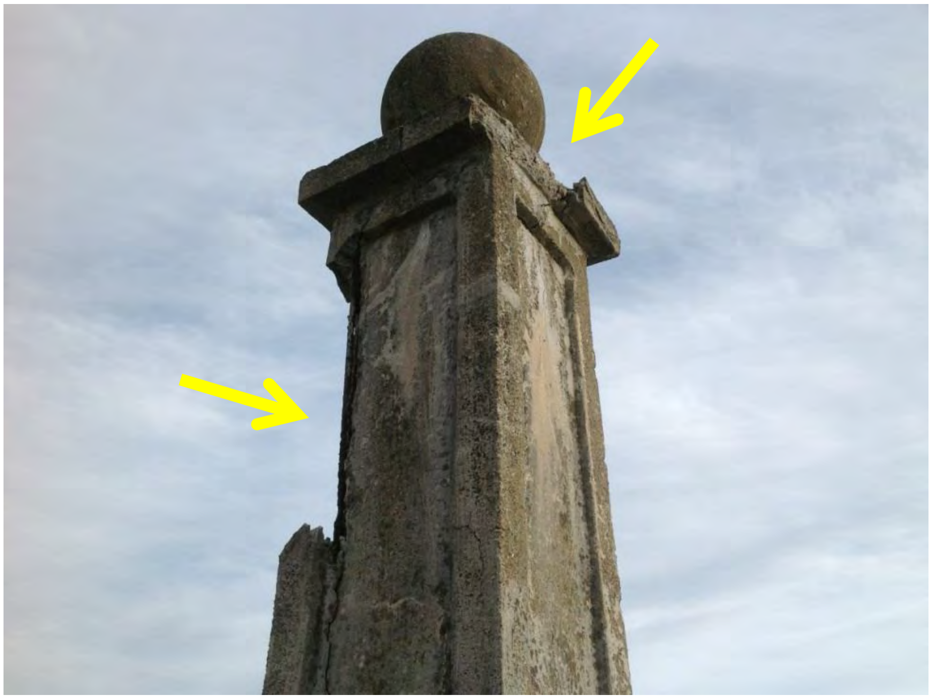

Figure 15. Spalls at west concrete pillar.

Figure 16. Vertical crack at west concrete pillar.

Figure 17. Vertical crack and abandoned anchors at east concrete pillar.

Figure 18. Cracked and spalled concrete at east field-level stairs.

Figure 19. Example of map cracking of horizontal surface at end of precast concrete seating elements.

Figure 20. Example of map-cracking at sloped transition between horizontal and vertical surfaces of precast concrete seating elements.

Figure 21. Example of cracking at sloped transition and vertical surface at end of precast concrete seating element.

Figure 22. Typical sealant failure at joint between precast concrete sections.

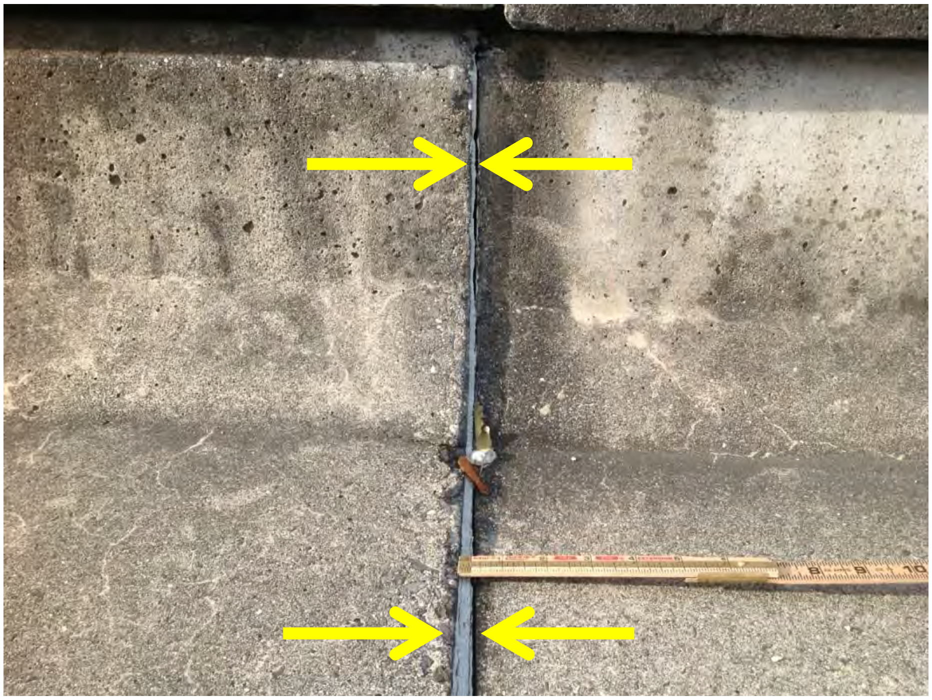

Figure 23. Example of variation in joint width between precast concrete sections.

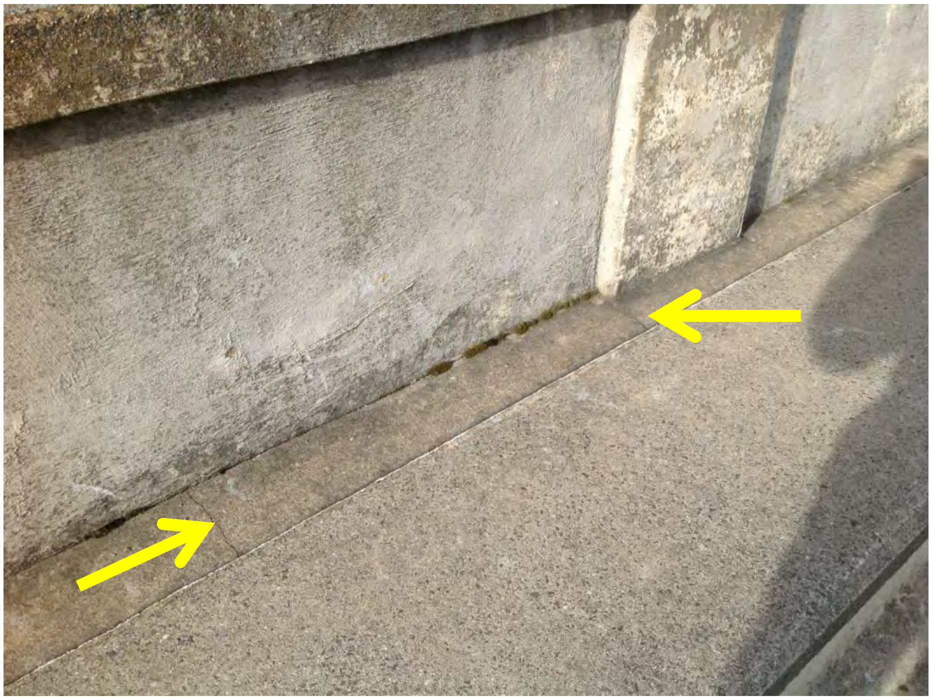

Figure 24. Cracking of concrete pour strip between precast concrete seating element and perimeter wall.

Figure 25. Typical cracking of precast concrete stairs.

Figure 26. Example of spall at corner of precast concrete seating element observed during initial site visit.

Figure 27. Patch installed by others at spalled concrete shown in Figure 26.

Figure 28. Existing concrete spalls at edge of seating element.

Figure 29. Delaminated concrete removed by WJE during the survey.

Figure 30. Window filled with opaque panel.

Figure 31. Window with rotted wood trim and frame plus a corroded and displaced metal grate.

Figure 32. Evidence of water infiltration at shower area ceiling.

Figure 33. Portion of locker room and maintenance building that lies outside of the bleachers.

Figure 34. Horizontal crack (arrow) at northeast corner of locker room and maintenance building and coating failure.

Figure 35. Spalled concrete at site stair foundation wall.

Figure 36. Delaminated concrete at site stair foundation wall.

Figure 37. Cracks and spalls at stair treads.

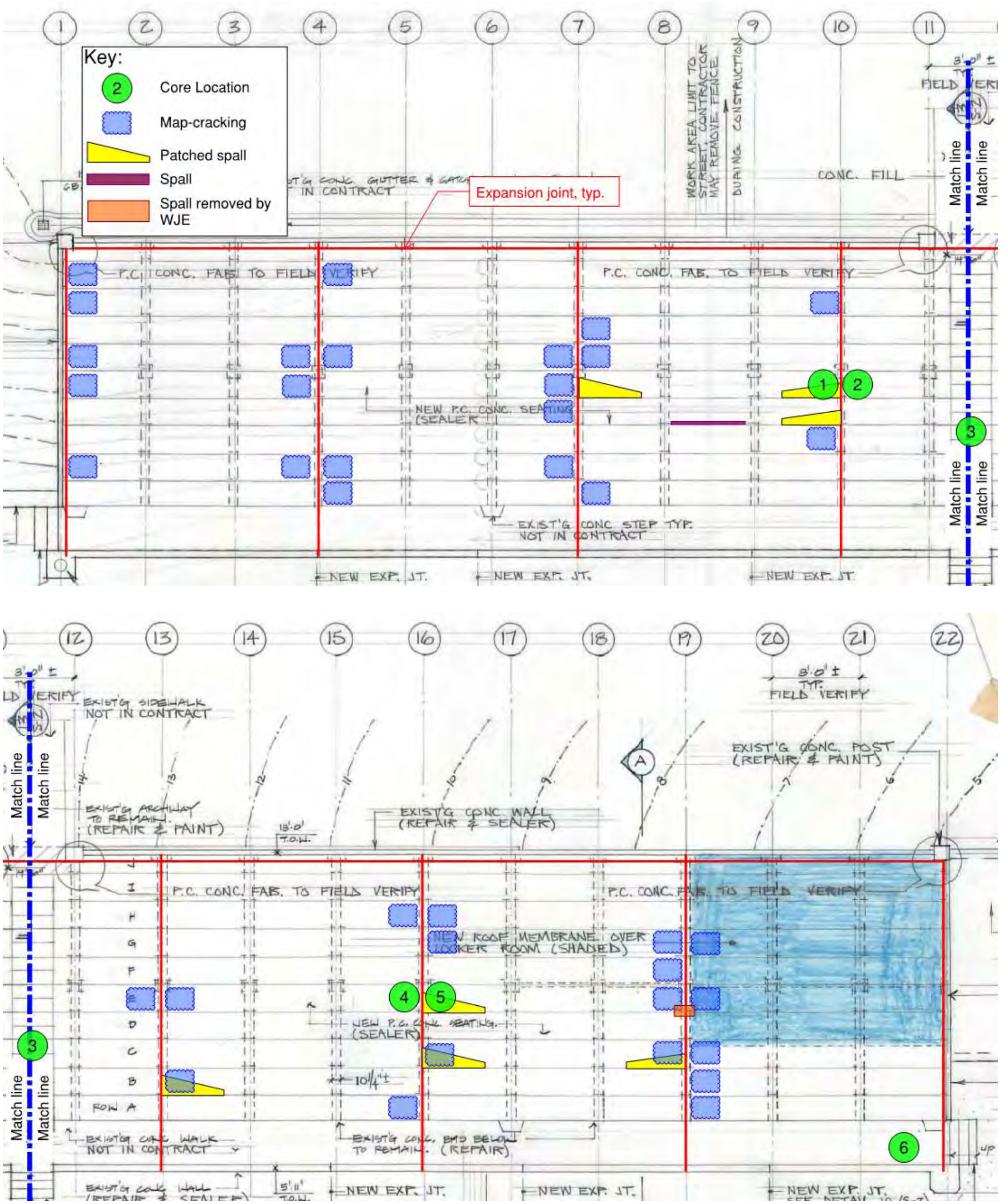

Figure 38. Plan view of precast concrete bleachers with locations of concrete cores, map-cracking, and spalls indicated.

APPENDIX A: OPINION OF COST TABLES

Option 1 - Scope of Work		Estimated Cost	Comments
ARCHWAY AND PILLARS			
Replace archway with new precast concrete archway.		$42,750	Demolish existing archway and replace with new precast concrete archway. New archway will be cast from two sides with a top coping unit. The existing lettering will be replicated on the new archway.
Replace pillars on either end of the bleachers.		$16,000	Demolish existing pillars at either end of the bleachers and replace with new precast concrete.
UPPER AND SIDE PERIMETER WALLS			
Replace upper and side perimeter walls.		$162,620	Demolish perimeter walls down to the grade-level foundation walls and install new cast-in-place concrete perimeter walls doweled into the existing walls below. Increase the wall thickness to a minimum of four inches to provide adequate concrete cover for reinforcing steel.
Coat upper and side perimeter walls.		$6,570	Apply new elastomeric coating.
LOWER PERIMETER WALL			
Concrete spall and crack repairs at lower perimeter wall.		$15,750	Replace delaminated concrete on top of and at vertical surfaces of lower perimeter wall. Patch wall areas at vertical cracks and control joints. Remove coating from wall.
Coat lower perimeter wall		$5,519	Apply new elastomeric coating.
FIELD-LEVEL STAIRCASES			
Replace all three field-level staircases.		$6,750	
PRECAST BLEACHERS			
Widen expansion joints at bleachers.		$7,210	Saw-cut expansion joints to be at least 1/2-inch wide between precast concrete seating elements to widen joints. Replace all sealant and backer rod at all control joints.
Repair spalled precast bleachers.		$5,330	Remove temporary patch material and square off repair areas at precast concrete seating elements. Repair with concrete patches properly designed and mechanically anchored to optimize service life.
Clean concrete surfaces.		$4,140	Clean concrete surfaces by abrasive blasting or water jetting.
Coat precast concrete bleachers.		$63,297	Apply new traffic-grade elastomeric coating to surfaces of precast concrete seating elements.
MISCELLANEOUS ELEMENTS			
Repair spalled concrete at site stairs and interior maintenance/locker room building.		$5,000	Remove spalled and delaminated concrete and install mechanically-anchored concrete patches at site stairs and overhead concrete at interior of maintenance/locker room building.
Repair concrete cracking at maintenance/locker room building.		$2,400	Rout out crack at northeast corner of the maintenance/locker room building and fill with multiple layers of sealant.
Replace window infills and window at maintenance/locker room building.		$7,500	
Base scope of work subtotal		$350,836	
Contingency	20%	$70,167	
Subtotal		$421,003	
Permits/Insurance	0.0125	$4,385	
Subtotal		$425,388	
Overhead & Profit	10%	$42,100	
Estimated Total		**$467,488**	

Option 2 - Scope of work		**Estimated Cost**	**Comments**
REPLACE CONCRETE BLEACHERS			
Replace concrete precast bleachers.		$365,710	Remove and replace existing concrete bleachers. Work includes crane rental during demolition and construction. Estimate provided is for an open precast concrete shop.
Applicable work from Option 1.		$264,289	Archway, pillar, wall, stair, and maintenance/locker room work from Option 1.
Base scope of work subtotal		$629,999	
Contingency	20%	$126,000	
Subtotal		$755,999	
Permits/Insurance	0.0125	$7,875	
Subtotal		$763,874	
Overhead & Profit	10%	$75,600	
Estimated Total		**$839,473**	

APPENDIX B: PETROGRAPHIC REPORT

SPY POND FIELD
Petrographic Studies of Concrete

Arlington, Massachusetts

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Final Report
December 18, 2013
WJE No. 2013.4548

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SPY POND FIELD
Petrographic Studies of Concrete

Arlington, Massachusetts

INTRODUCTION

At the request of Emma Cardini of WJE's Boston office, petrographic studies were conducted for nine samples of concrete that were removed from Spy Pond Field in Arlington, Massachusetts. Six of the samples were concrete cores. Five of the cores were extracted from precast concrete bleachers that were constructed in the 1980s. The sixth core represents a concrete walkway at the base of the bleachers. The date of construction of the walkway is unknown. The remaining three samples consisted of irregularly- shaped concrete fragments removed from three architectural elements (arch, coping and pillar) and represent the "original" concrete that has been in service since about 1912. Portions of the concrete represented by all the samples are reportedly exhibiting deterioration. The studies were requested to characterize the concrete and determine the cause(s) of the reported deterioration. In addition, compression strength testing was requested on one of the intact concrete core samples extracted from the bleachers.

SAMPLES

The nine samples that were received for the studies are described in Table 1. The as-received appearance of the samples is shown in Appendix Figures A1 through A36. Three of the five cores extracted from the bleachers represented concrete that exhibited significant deterioration (Appendix Figures A1 through A20). The concrete core extracted from the walkway was intact (Appendix Figures A21 through A24). All six cores are 2-3/4 inches in diameter and (with the exception of Core 3) approximately 3 inches in length. Core 3 was 7-1/2 inches in length. The bottom 5-1/2 inches was cut from this core in the laboratory, and that portion of it was used for compression strength testing.

The top surfaces of the cores and the plane surfaces of the fragments exhibit signs of weathering. The cementitious matrix that was originally present on the exposed surfaces had eroded away, and sand particles were exposed. With the exception of Core 6, the bottoms of the cores are fracture surfaces. The bottom of Core 6 is a formed surface, and the sample is assumed to represent the full thickness of the walkway. The three concrete fragments represent "original" concrete that exhibits evidence of internal distress (Appendix Figures A25 through A36). The non-planar surfaces of the concrete fragments are fracture surfaces.

STUDIES

With the exception of the bottom 5-1/2 inches of Core 3, all of the samples were examined petrographically using methods outlined in ASTM C856, *Standard Practice for Petrographic Examination of Hardened Concrete*. Slabs were cut lengthwise from the center of each core using a water-cooled continuous-rim diamond saw. The resulting plane surfaces were then lapped using progressively finer silicon carbide abrasives (Figure 1). The lapped surfaces and the remainders of the cores were then examined microscopically. Thin sections representing the top 1-1/2 inches of Cores 2 and 5 were prepared and examined using a polarized light (petrographic) microscope. Sawed surfaces were also prepared for the three irregularly-shaped fragments that had been removed from the arch, coping and

pillar of the “original” structure. The sawed surfaces were oriented perpendicular to the planar exposed surfaces of these samples. Several of the resulting sawed surfaces were also lapped (Figure 2).

The bottom 5-1/2 inches of Core 3 was cut from the intact submitted sample and tested in compression according to ASTM C42, *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*.

Volumes of the coarse aggregate, fine aggregate, cementitious matrix and air were estimated for the six cores using the modified point-count method outlined in ASTM C457, *Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete*. The parameters of the air void system were additionally measured for the three cores that were judged to be air-entrained (Cores 2, 3 and 6). Refer to Table 2 for the results.

Precast Concrete Bleachers (Concrete Cores 1-5)

The crushed stone coarse aggregate contained in Cores 1 through 5 consisted of fine-grained metamorphic rocks (Figure 3). Individual coarse aggregate particles are foliated and contain regions that- when examined at high magnification- have textural features consistent with quartzite. Individual quartz grains contained in these regions often exhibit undulatory extinction. Veins of calcite were detected within some of the particles. Concentrations of muscovite that also contained very fine-grained quartz gave other portions of the particles a phyllitic[1] texture. Some of the coarse aggregate particles contain a darkened rim around their perimeters (Figure 4). The coarse aggregate particles were angular and uniformly distributed. They had a maximum nominal size of 3/8 inch. The fine aggregate is similar in composition to the coarse aggregate, indicating it is likely manufactured sand.

Many of the coarse aggregate particles contained in the cores exhibited internal fractures (Figure 5). In the case of the non-air-entrained concrete represented by Cores 1, 4 and 5, internal cracks travel through the coarse aggregate particles and extend outward into the adjacent matrix (Figures 6a and 6b). The fractures in the upper portions of the Cores 1 and 4 are oriented approximately parallel to the tops of the cores. These fractures are indicative of freeze-thaw distress. They are commonly partially filled with ettringite.

Fractures located nearer the bottoms of the cores and that extended outward from coarse aggregate particles contained silica gel (Figures 7a and 7b). In addition, some of the internally fractured coarse aggregate particles had darkened rims. The fractures are indicative of deleterious expansion associated

[1] According to ASTM C294, *Standard Descriptive Nomenclature for Constituents of Concrete Aggregates,* phyllites are classified as potentially deleteriously reactive with alkalis in the paste.

with alkali-silica reaction (ASR). Air voids adjacent to some of these fractures were also filled with silica gel (Figures 8a and 8b).

A few intact aggregate particles were encompassed by a rim of anisotropic (crystalline) material composed of ettringite (Figure 9). This feature has previously been detected in precast concrete that suffered deleterious expansion due to delayed ettringite formation (DEF). Studies using the scanning electron microscope (SEM) would be needed to more fully characterize these ettringite deposits to determine if the concrete had been affected by DEF or if this feature resulted from disruption associated with the combination of freeze-thaw distress and ASR clearly identified in the concrete.

The cementitious matrix contains residual portland cement. No supplementary cementitious materials (SCMs) such as fly ash were detected. The matrix of Cores 1 through 5 is hard and cannot be scratched using a copper probe. Color variations between the cores suggest variable w/c between the concrete mixes. Cement particles with clear rims around the perimeter were detected in the thin section representing Core 5. Some residual (unhydrated) portland cement particles were detected when phenolphthalein indicator solution was applied to lapped surfaces. This condition suggests the potential for continued cement hydration which will release additional calcium hydroxide and tend to keep the cementitious matrix alkaline. Macro and microcracks oriented roughly parallel to the top surfaces of Cores 1, 2 and 5 were present in the cementitious matrix (Figures 6 and 10). These fractures passed uninterruptedly through some coarse aggregate particles (Figure 6a). These fractures are consistent with freeze-thaw distress. The cracks continued through the full depth (2-1/2 inch) of Core 1. Ettringite was present in the cracks. These interconnected fractures have allowed water to migrate through the concrete and secondary deposits of ettringite were subsequently deposited in them (Figure 6b).

The cementitious matrix of the cores contains varying levels of air entrainment (Table 2). Cores 2 and 3 are air-entrained (Figure 11a), and Cores 1, 4 and 5 are not air-entrained (Figure 11b). The parameters of the air void system were measured for the two air-entrained samples (Cores 2 and 3), and the constituent volumes of concrete components for all the cores are presented in Table 2. The spacing factor and specific surface values are generally outside the range associated with good freeze-thaw durability. However, no evidence of significant freeze-thaw-induced stress was detected in these two air-entrained cores. (Minor numbers of microcracks oriented parallel to the top surface were detected in Core 2.) The air voids are often partially or fully filled with ettringite (Figure 12). The deposition of ettringite in voids was not associated with deleterious expansion. Deposits in voids also stained red, indicating the presence of calcium, and had other features consistent with ASR gel (Figures 7b and 13). The presence of secondary deposits that partially to completely filled many of the air voids in Cores 2, 3 and 6 have reduced the effectiveness of the entrained air void system. This will likely increase the vulnerability of the concrete to subsequent freeze-thaw distress.

Fresh fracture surfaces were prepared in the laboratory. Phenolphthalein indicator solution was applied to the fracture surfaces to measure the depth of carbonation of the cementitious matrix. Carbonation of the near-surface matrix was present in all of the cores and was measured at a maximum depth of 1/8 inch. Inter-core variations in constituent volumes were detected (Table 2). This variation is consistent with the observed variations in estimated unit weights for the cores. If the cores represent multiple mixed batches of concrete (as might be expected for precast bleachers), the variations in constituent volumes could be indicative of batch-to-batch variability. The average paste content is consistent with a 5-1/2 to 6 sack mix.

Compression Strength Testing

The bottom of Core 3 was tested for compression strength according to ASTM C42. The compression strength of the core was 8730 psi. Core 3 is air-entrained, and no evidence of freeze-thaw distress was detected in the portion of the submitted core that was examined petrographically. It should be noted that even if cracking associated with freeze-thaw or ASR-induced distress was present, if the planes of the cracks were oriented perpendicular to the axis of the core used for compression strength evaluation, a significant decrease in strength may not be detected.

Concrete Walkway (Concrete Core 6)

The coarse and fine aggregate contained in Core 6 is similar to that present in Cores 1 through 5. Coarse aggregate representing larger sieve sizes were absent from the concrete mix represented by Core 6 (Figure 1). The concrete was air-entrained, and voids were commonly partially lined with deposits of ettringite. Features indicating freeze-thaw distress or ASR were not detected in the core. Water voids in Core 6 were detected in a band roughly 1 inch below the top surface (Figure 14). No distress was associated with the water voids. Portland cement was detected in the cementitious matrix.

The fresh fracture surface prepared in the laboratory was treated with phenolphthalein indicator solution. Carbonation was measured to a depth of 1/4 inch from the top surface. Carbonation had occurred adjacent to the curved core surfaces of Core 6, to a depth of 1/8 inch, after this sample had been extracted from the walkway. This condition has previously been observed for concrete that has a relatively high w/c (Figure 15). The matrix on the fracture surface had a vitreous luster and readily absorbed water.

Core 6 appears to represent an entirely different concrete than that represented by Cores 1-5 based on results from the ASTM C457 studies (Figure 1 and Table 2). Inspection of Table 2 indicates this mix has significantly different sand-to-aggregate ratio (by volume) than the other cores.

"Original" Architectural Concrete (Concrete Fragments)

The arch, coping and pillar fragments represent "original" concrete that was reported to have been in service since 1912. The exposed surfaces contain exposed fine aggregate indicating that the cementitious matrix originally present on the surface has eroded away. The extent of erosion is not judged to be excessive given the age of the element. The aggregate in the three samples is similar and consists of igneous rocks. The concrete mix design volumes varied between samples. Features characteristic of ASR were not detected in the samples.

The arch fragment represents a mortar-like mix that contains some relatively coarse-graded, angular sand particles. The arch sample is air-entrained. No features consistent with freeze-thaw distress are detected. Some voids are partially lined with white, secondary deposits. The matrix is hard and could not be scratched with a copper probe. There is a band of darkened matrix along the exterior surfaces of the sample that may represent a parge coat (Figure 16).

One of the exterior surfaces of the coping fragment had been coated with a layer of mortar that appeared to be contemporaneous with the underlying concrete (Figure 17). Coarsely ground, residual portland cement particles were present in the topping mortar. Irregularly-shaped voids in the mortar are partially or fully filled with white, secondary deposits. This mortar does not appear to show signs of distress. The concrete in the body of the coping sample is also not air-entrained. Voids were partially filled with white secondary deposits. Microcracks characteristic of minor freeze-thaw distress were present in the body of

the sample.

The pillar sample is not air-entrained and exhibited severe distress that appears to be related to freeze-thaw damage (Figure 18). Voids were partially filled with white secondary deposits.

SUMMARY AND DISCUSSION

Cores 1 and 5 are non-air-entrained and contain fractures that are indicative of advanced freeze-thaw distress. Secondary deposits that coat these fracture surfaces confirm that moisture has migrated through the concrete. Although Cores 2, 3 and 4 are air-entrained, secondary deposits in many of the air voids would be expected to reduce the effectiveness of the air void system. Thus concrete represented by these cores may eventually become susceptible to freeze-thaw distress

In addition to the freeze-thaw distress, evidence of active ASR was present in the precast concrete bleacher cores. The ASR distress appears to be localized near the bottoms of the cores. The concrete is made with crushed fine-grained metamorphic coarse and fine aggregate that had textural features consistent with both quartzite and phyllite. This type of aggregate is classed as potentially deleteriously reactive with cement alkalis. The presence of silica gel in voids and along fractures located in the lower portions of the cores in combination internally fractured coarse aggregate particles that exhibit darkened rims is consistent with deterioration due to ASR.

The presence of a few aggregate particles that are surrounded around their perimeters by ettringite has previously been detected in concrete that has suffered from deleterious expansion of the matrix associated with delayed ettringite formation (DEF). Since secondary deposits of ettringite are also associated with freeze-thaw distress, additional studies using the scanning electron microscope would be necessary fully characterize these features of the cementitious matrix in an attempt to determine if DEF may also have contributed to the observed distress.

The significant core-to-core variation in aggregate volumes and levels of air entrainment are consistent with batch-to-batch variations in the concrete used to fabricate the bleacher elements represented by Cores 1-5. Core 6 represents an entirely different concrete mix than the five cores extracted from the precast concrete bleacher. Although concrete represented by this core has an elevated w/cm and is deficient in coarse aggregate volume, it is air-entrained and does not exhibit freeze-thaw-related distress.

The compression strength for the bottom portion of Core 3 was 8730 psi. Evidence of deleterious expansion due to ASR was detected in the top portion of Core 3 examined microscopically. Crack planes, if oriented perpendicular to the direction of loading, may not necessarily have an adverse effect on compression strength of the core.

The two fragments of historic architectural concrete (coping and pillar) have both suffered from advanced freeze-thaw distress.

The fragment of the historic arch is composed of a mortar-like mix that is functionally air-entrained. It has a relatively high cement factor relative to the coping and pillar fragments. Since mortars typically have higher cement factors, they often have lower w/cm than concrete. Depending on the mixing method, mortar may also become “naturally” air-entrained. So it was possible to obtain good freeze-thaw durability for a highly workable mortar.

The thin mortar layer on the horizontal surface of the coping was most likely installed in an effort to increase the durability of the element. This layer has a conspicuously lower water to cement ratio than the underlying body of the concrete and would be expected to reduce water penetration into the element. Unfortunately, subsequent cracking of the coping allowed water penetration into the non-air-entrained body of the element. No evidence of ASR was present in these three samples of historic concrete.

Storage: **Thirty days after completion of our studies, samples will be discarded unless the client submits a written request for their return. Shipping and handling fees will be assessed for any samples returned to the client. Any hazardous materials that may have been submitted for study will be returned to the client and shipping and handling fees will apply. The client may request that WJE retain samples in storage in our warehouse. In that case, a yearly storage fee will apply.**

Table 1. Spy Pond Field Bleacher Submitted Samples

Sample ID	Element	Description	Concrete Distress	Testing Performed
1	Core	Precast bleachers	Y	Petrographic examination
2	Core	Precast bleachers	N[2]	Petrographic examination
3	Core	Precast bleachers - stair riser	Y	Petrographic examination, Compression
4	Core	Precast bleachers	N	Petrographic examination
5	Core	Precast bleachers	Y	Petrographic examination
6	Core	Walkway at base of bleachers	N	Petrographic examination
Arch	Fragment	Original arch	N	Visual examination
Coping	Fragment	Original wall at back of bleachers	Y	Visual examination
Pillar	Fragment	Original decorative pillar	Y	Visual examination

[2] Core 2 was reported to not exhibit visual signs of concrete distress; however, upon examination, freeze-thaw deterioration was observed.

Table 2. Estimated Constituent Volumes for Cores 1-6 from Spy Pond Field Bleachers

	Constituent Volumes						Usual Requirements
Sample Identification	**Core 1**	**Core 2**	**Core 3**	**Core 4**	**Core 5**	**Core 6**	**--**
Air Content (%)	0.6	7.7	4.9	3.0	2.0	8.0	5 to 8
Paste Content (%)	30.4	30.3	33.4	32.3	30.4	25.0	--
Sand Content (%)	16.0	24.3	28.2	29.4	26.3	36.6	--
Coarse Aggregate (%)	53.0	37.6	33.4	35.3	41.2	30.5	--
Unit weight (lb./cu.ft.)	151.3	143.8	146.2	152.1[3]	150.9	139.9	
Number of Voids/inch	--	4.42	5.8	--	--	9.68	Greater than the percent of entrained air
Average Chord Intercept (inch)	--	0.0175	0.0085	--	--	0.0083	--
Specific Surface (in^2/in^3)	--	228	471	--	--	482	Greater than 600
Spacing Factor (inch)	--	0.0171	0.0113	--	--	.0064	Less than 0.008

[3] Core contained steel reinforcing mesh that was not removed prior to testing.

FIGURES

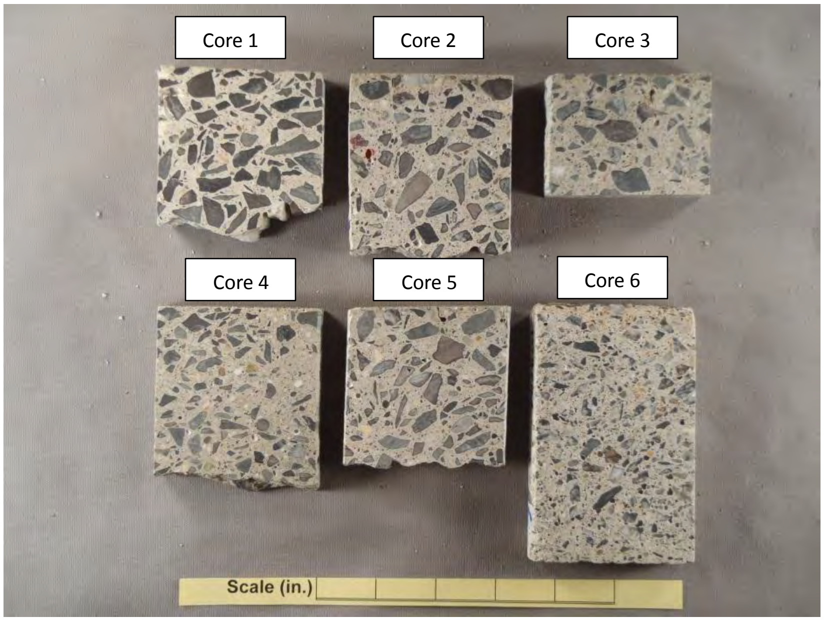


Figure 1. The lapped surfaces of Cores 1 through 6 are pictured. Cores 1 through 5 represent the precast concrete bleachers, and Core 6 represents a walkway at the base of the bleachers.

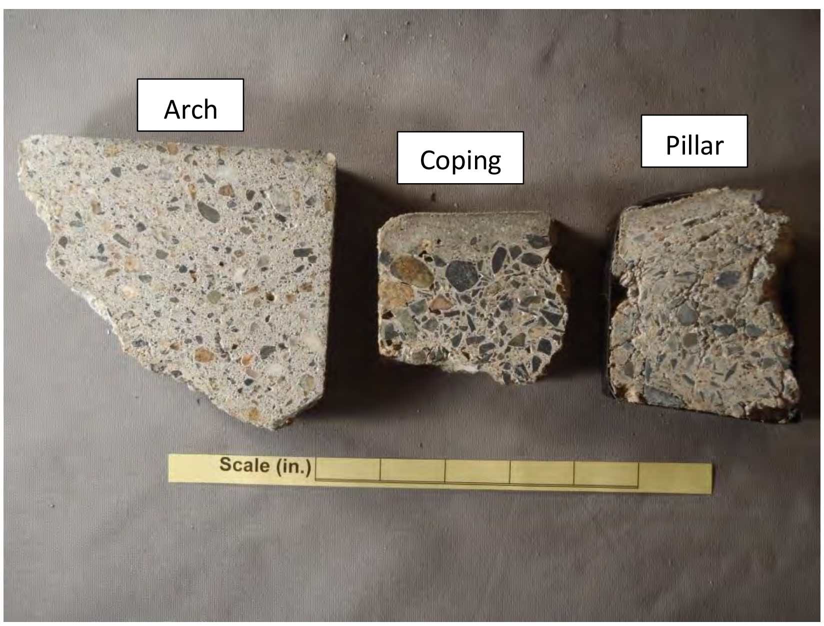


Figure 2. The lapped surfaces of the three fragments representing architectural elements from the "original" 1900s concrete are pictured. The arch, coping and pillar are pictured from left to right, respectively.

Figure 3. The lapped surface of Core 5 is pictured. The coarse aggregate consists of fine-grained metamorphic rocks known to be potentially reactive to alkalis. The aggregate is consistent between Cores 1-6. ASR was detected in Cores 1-5.

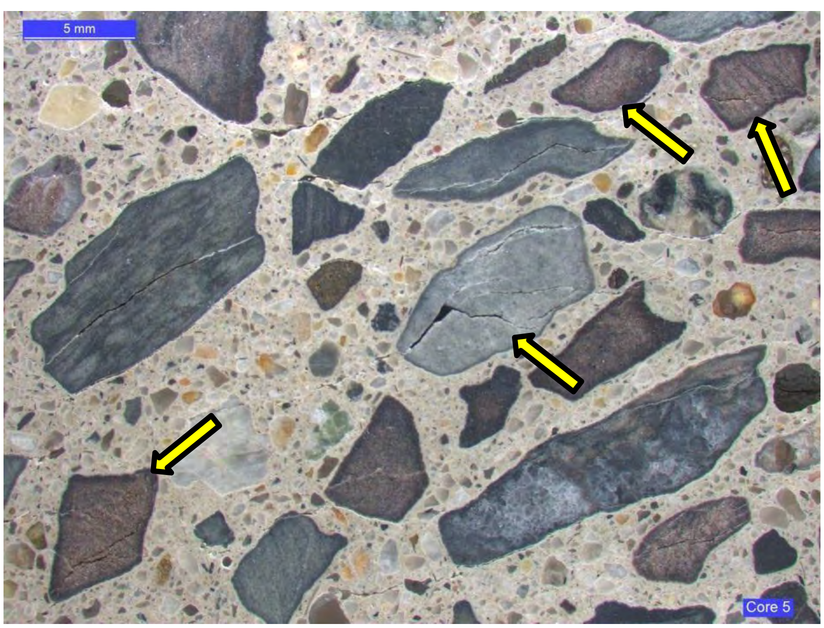
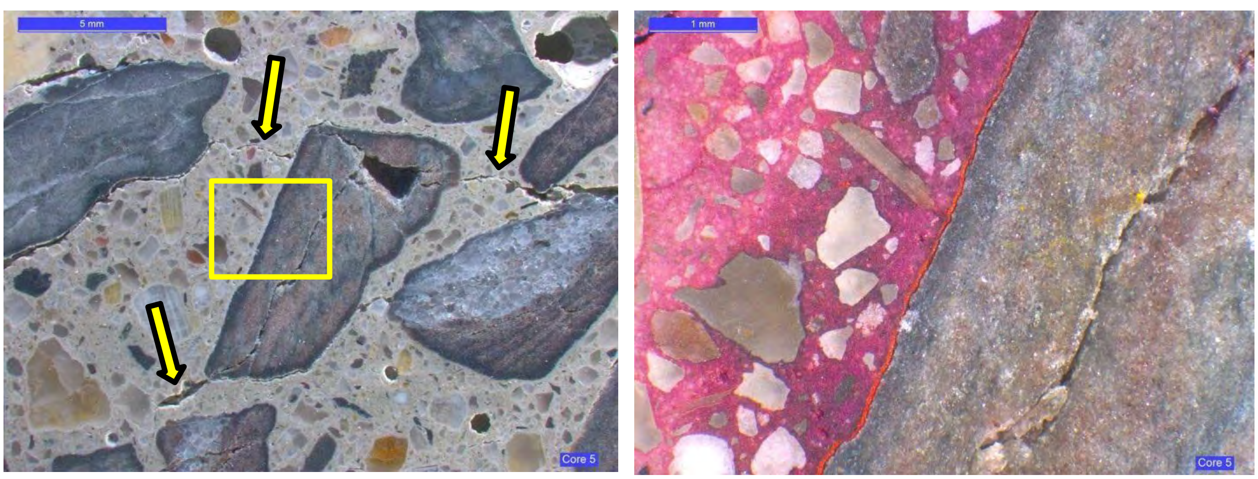
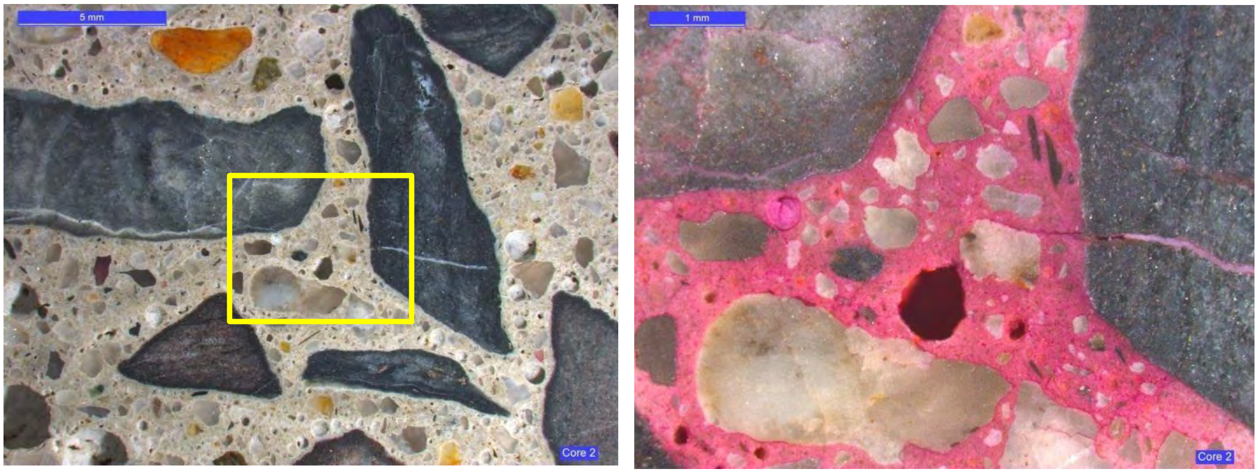


Figure 4. A portion of the lapped surface in Core 5 is pictured. Some coarse aggregate particles have darkened rims around their perimeter (arrows) suggesting a reaction with the aggregate has taken place.

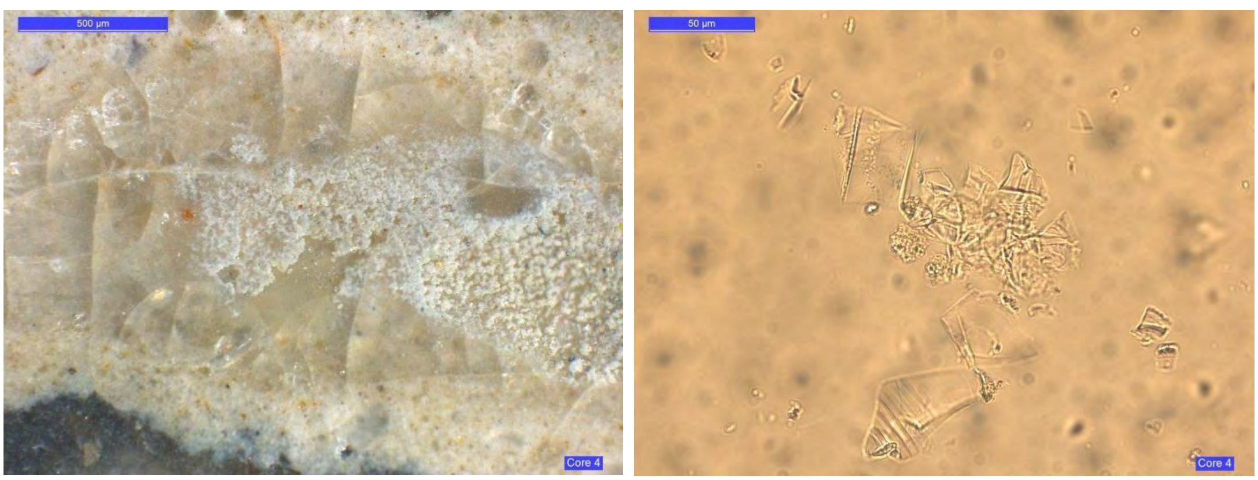
Figure 5. An aggregate on the lapped surface of Core 2 is pictured. The aggregate contains numerous internal fractures.



Figures 6a and 6b. An aggregate on the lapped surface of Core 5 is pictured on the left. The boxed region is pictured at higher magnification and after the application of Alizarin Red S dye on the right. Freeze-thaw induced cracks are marked with arrows and intersect the aggregate particle. The aggregate is surrounded by a thin band of secondary deposits of ettringite (stained orange with dye).



Figures 7a and 7b. A portion of the lapped surface in Core 2 is pictured on the left and the boxed region at higher magnification and after the application of Alizarin Red S dye on the right. Internal fractures through aggregates extend into the adjacent cementitious matrix and are filled with gel. The gel stained red, indicative of calcium-containing gel.



Figures 8a and 8b. An irregularly-shaped void filled with secondary deposits in Core 4 is pictured on the left. The deposits were scraped from the surface of the lapped surface and examined using a polarized light microscope with a refractive index oil of 1.49. The fragment immersed in oil is pictured with transmitted light on the right image. The deposits had a refractive index less than 1.49, had a low relief and were isotropic. These features are consistent with ASR gel.

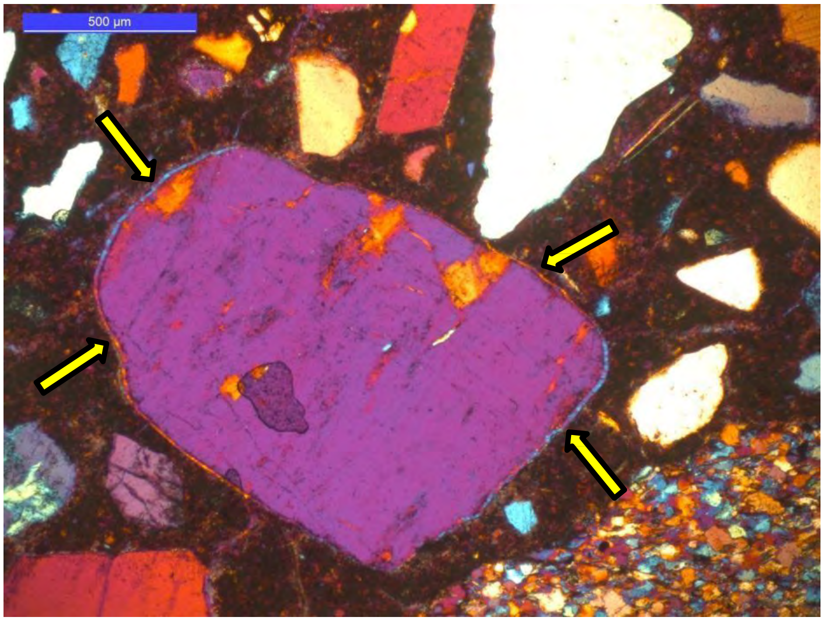


Figure 9. A portion of the thin section of Core 5 using cross-polarized light with the gypsum plate is pictured. The coarse aggregate particle is fully surrounded by a thin void filled with a secondary deposit (arrows). The deposits had features consistent with ettringite.

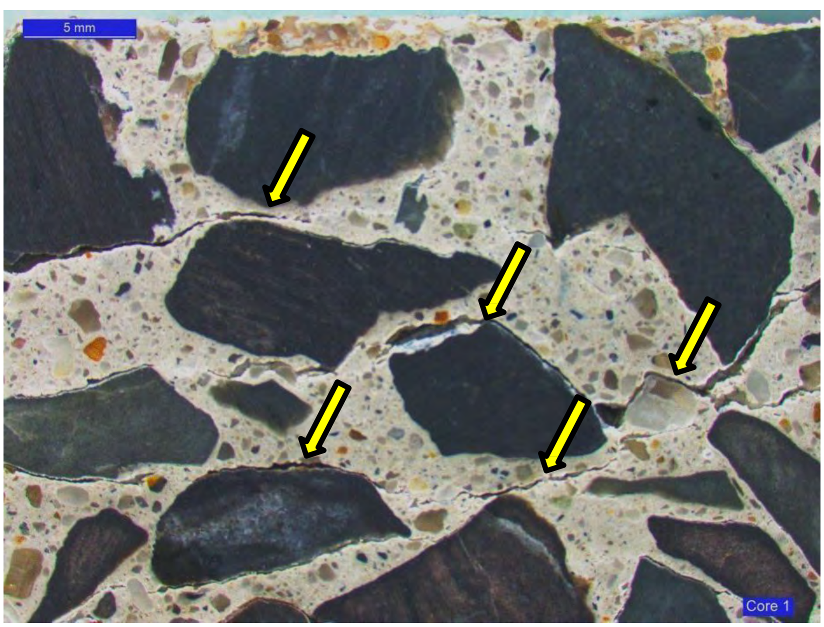
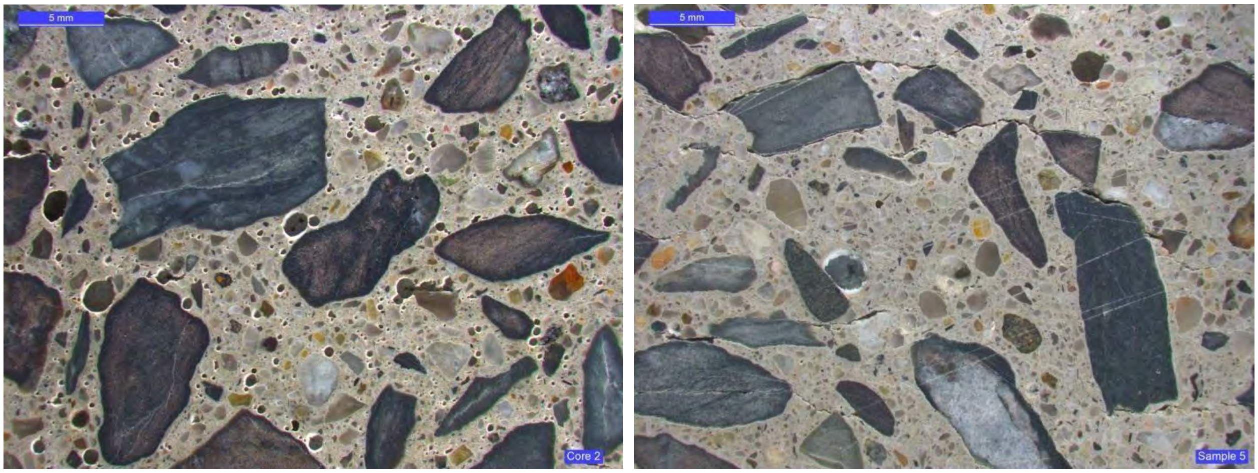


Figure 10. A portion of the near-surface region of Core 1 is pictured. Macrocracks oriented parallel to the top surface and parallel to one another are marked with arrows. Cracking extended through the full core width. This crack pattern is typical of freeze-thaw distress.



Figures 11a and 11b. A portion of the lapped surfaces of Core 2 and Core 5 is pictured on the left and right, respectively, using low-angle lighting. Voids appear as dark spots. Core 2, along with Cores 3 and 6, were air-entrained. Core 5, along with Cores 1 and 4, were not air-entrained.

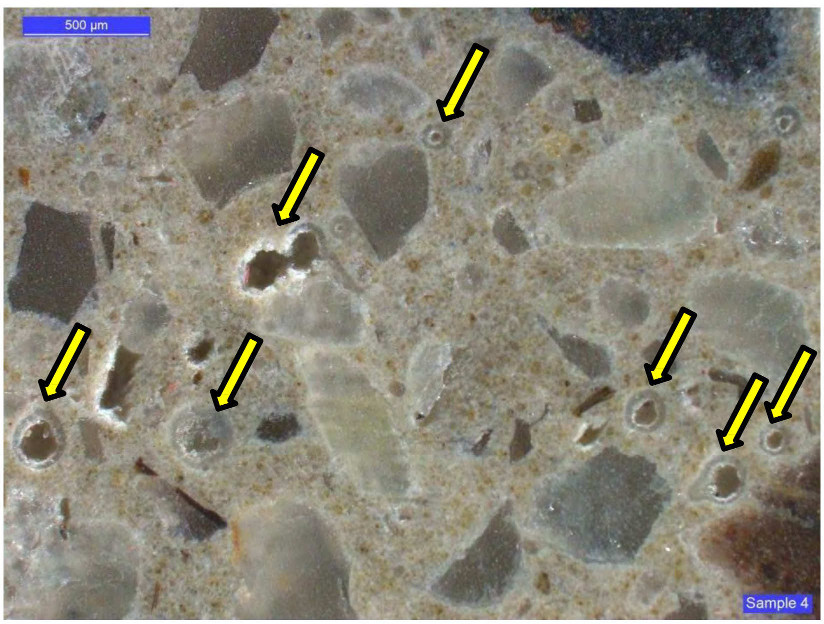


Figure 12. Air voids on the lapped surface of Core 4 are pictured. Voids are partially filled with white secondary deposits that had features consistent with ettringite (arrows). Voids filled with deposits compromise the functional air void system.

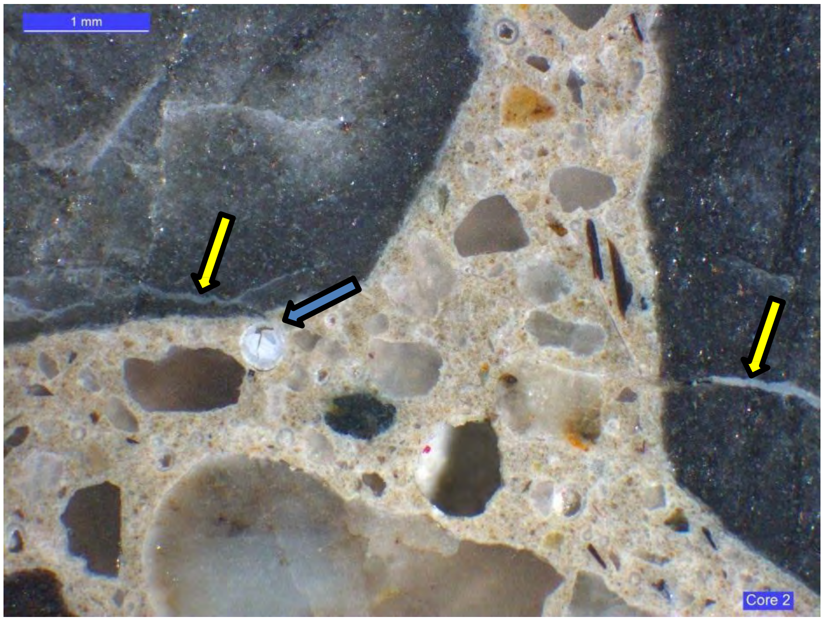


Figure 13. A portion of the lapped surface of Core 2 is pictured. Gel-filled cracks are marked with yellow arrows in the coarse aggregates. An entrained air void intersected by a crack is filled with ASR gel (blue arrow).

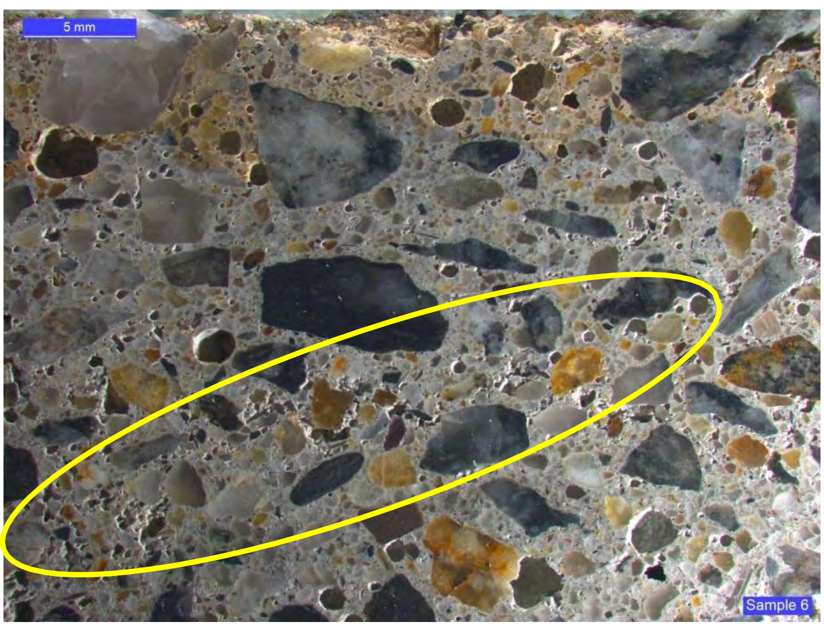


Figure 14. A portion of the lapped surface in Core 6 is pictured using low-angle lighting. A band of matrix roughly 1 inch below the surface contains numerous water voids.

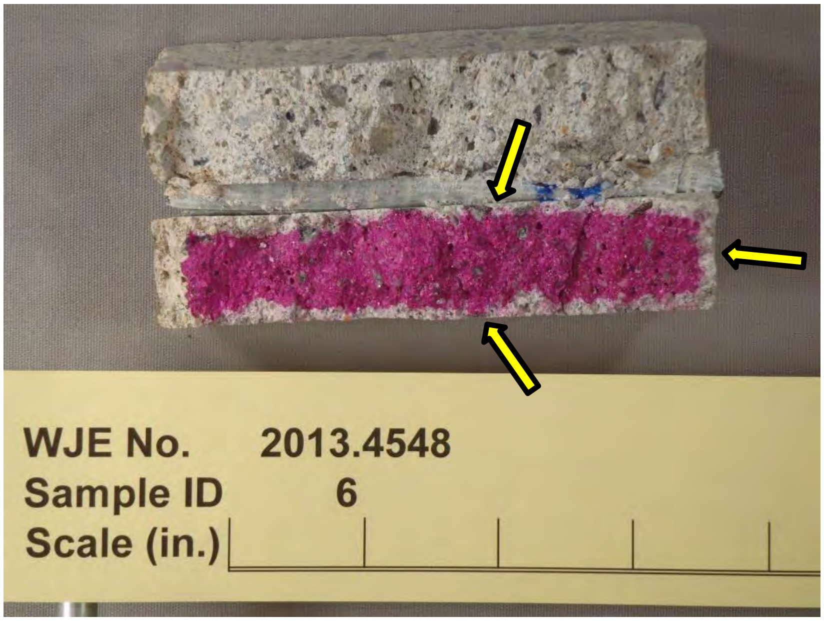


Figure 15. A fresh fracture surface in Core 6 is pictured with the top of the core to the left of the image. Phenolphthalein indicator solution was applied to one of the fracture surfaces. The pink color indicates no carbonation of the cementitious matrix has occurred. Note the carbonation from the curved core perimeter and bottom (arrows), suggesting carbonation since the core had been extracted. This features are consistent with a high w/c.

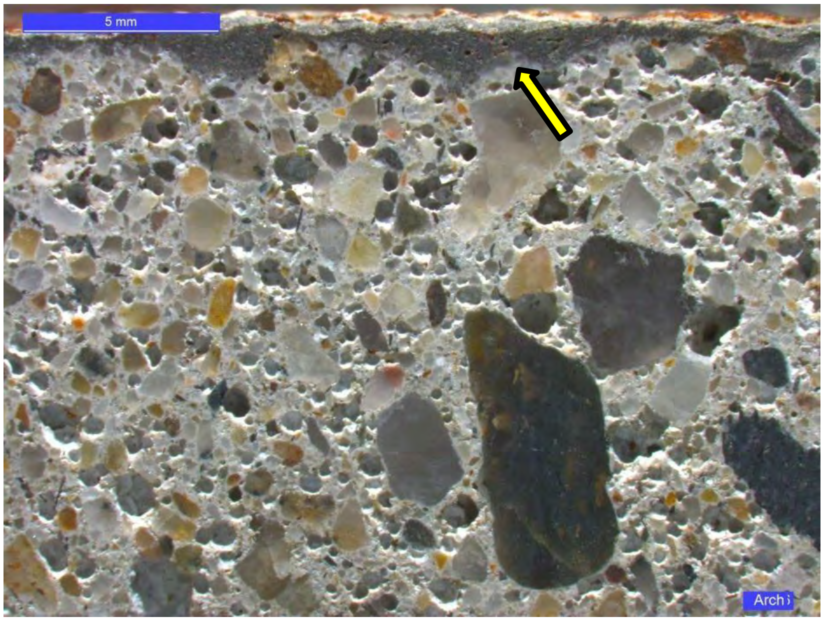


Figure 16. A portion of the near-exterior surface of the Arch is pictured using low-angle lighting. Note the band of darkened matrix along the exterior surface (arrow). The concrete represented by the sample was air-entrained.

Figure 17. A portion of the lapped surface near the exterior surface of the Coping is pictured. Mortar was present along one of the exterior surfaces. The concrete in the body of the sample contains numerous irregularly-shaped voids. Voids are commonly lined with white secondary deposits.

Figure 18. The lapped surface of the Pillar is pictured using low-angle lighting. Numerous macrocracks were present through the full-depth of the sample. This deterioration is characteristic of freeze-thaw distress.

APPENDIX A

Appendix A. As-Received Appearance of the Submitted Sample

Figure A1. The as-received appearance of the top of Core 1 is pictured using low-angle lighting.

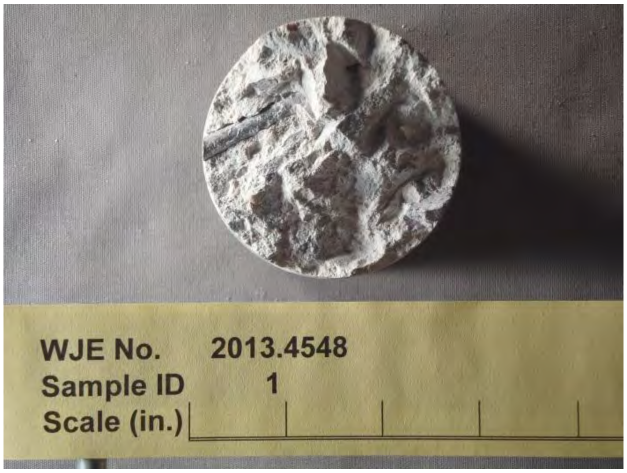


Figure A2. The as-received appearance of the bottom of Core 1 is pictured using low-angle lighting.

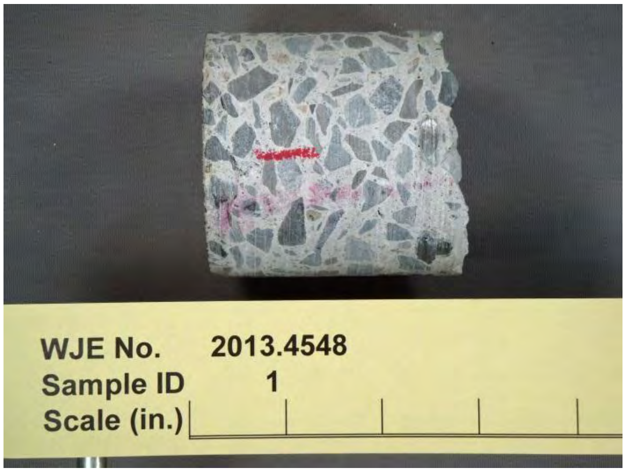


Figure A3. The as-received appearance of the side of Core 1 is pictured.

Figure A4. The as-received appearance of the side of Core 1 is pictured.

Figure A5. The as-received appearance of the top of Core 2 is pictured using low-angle lighting.

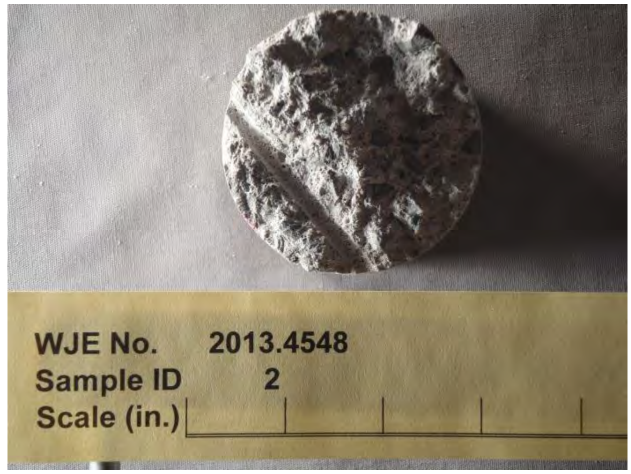


Figure A6. The as-received appearance of the bottom of Core 2 is pictured using low-angle lighting.

Figure A7. The as-received appearance of the side of Core 2 is pictured.

Figure A8. The as-received appearance of the side of Core 2 is pictured.

Figure A9. The as-received appearance of the top of Core 3 is pictured using low-angle lighting.

Figure A10. The as-received appearance of the bottom of Core 3 is pictured using low-angle lighting.

Figure A11. The as-received appearance of the side of Core 3 is pictured.

Figure A12. The as-received appearance of the side of Core 3 is pictured.

Figure A13. The as-received appearance of the top of Core 4 is pictured using low-angle lighting.

Figure A14. The as-received appearance of the bottom of Core 4 is pictured using low-angle lighting.

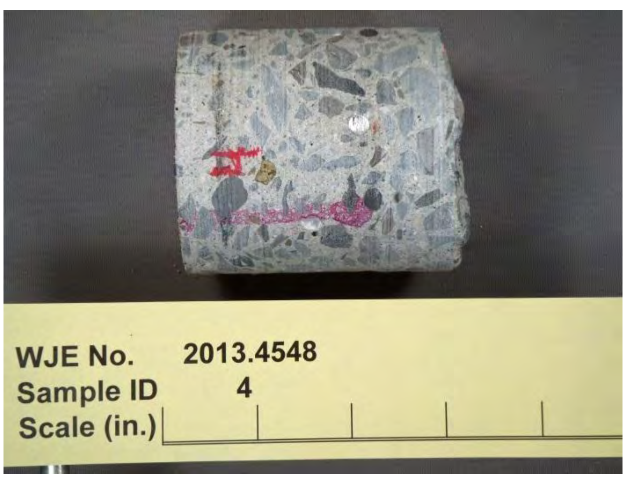


Figure A15. The as-received appearance of the side of Core 4 is pictured.

Figure A16. The as-received appearance of the side of Core 4 is pictured.

Figure A17. The as-received appearance of the top of Core 5 is pictured using low-angle lighting.

Figure A18. The as-received appearance of the top of Core 5 is pictured using low-angle lighting.

Figure A19. The as-received appearance of the side of Core 5 is pictured.

Figure A20. The as-received appearance of the side of Core 5 is pictured.

Figure A21. The as-received appearance of the top of Core 6 is pictured using low-angle lighting.

Figure A22. The as-received appearance of the top of Core 6 is pictured using low-angle lighting.

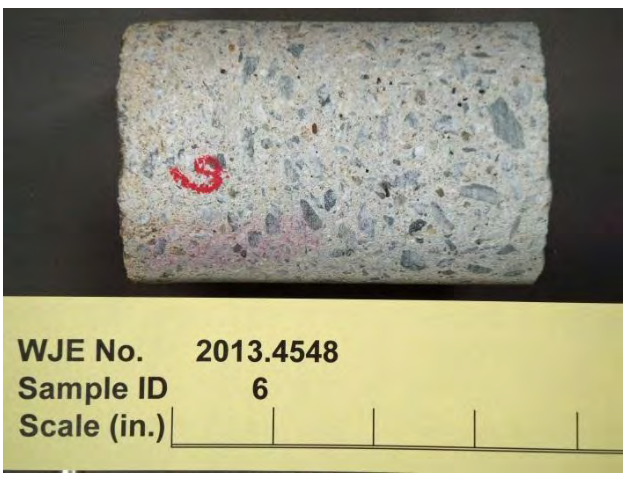


Figure A23. The as-received appearance of the side of Core 6 is pictured.

Figure A24. The as-received appearance of the side of Core 6 is pictured.

Figure A25. The as-received appearance of the side of the Arch is pictured using low-angle lighting.

Figure A26. The as-received appearance of the side of the Arch is pictured using low-angle lighting.

Figure A27. The as-received appearance of the side of the Arch is pictured.

Figure A28. The as-received appearance of the side of the Arch is pictured.

Figure A29. The as-received appearance of the side of the Coping is pictured using low-angle lighting.

Figure A30. The as-received appearance of the side of the Coping is pictured using low-angle lighting.

Figure A31. The as-received appearance of the side of the Coping is pictured.

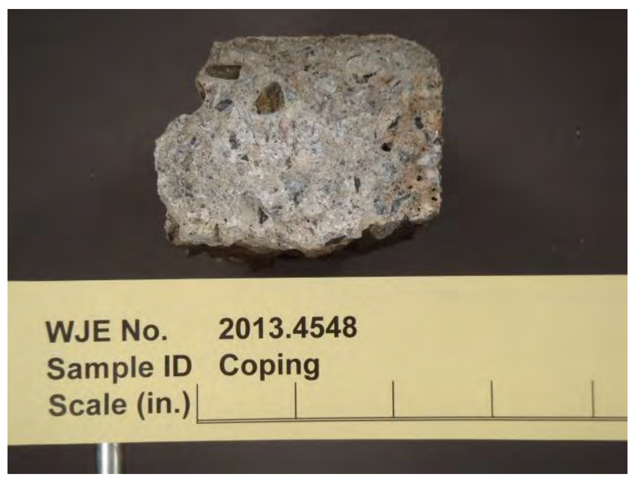


Figure A32. The as-received appearance of the end of the Coping is pictured.

Figure A33. The as-received appearance of the side of the Pillar is pictured using low-angle lighting.

Figure A34. The as-received appearance of the side of the Pillar is pictured using low-angle lighting.

Figure A35. The as-received appearance of the side of the Pillar is pictured.

Figure A36. The as-received appearance of the end of the Pillar is pictured.